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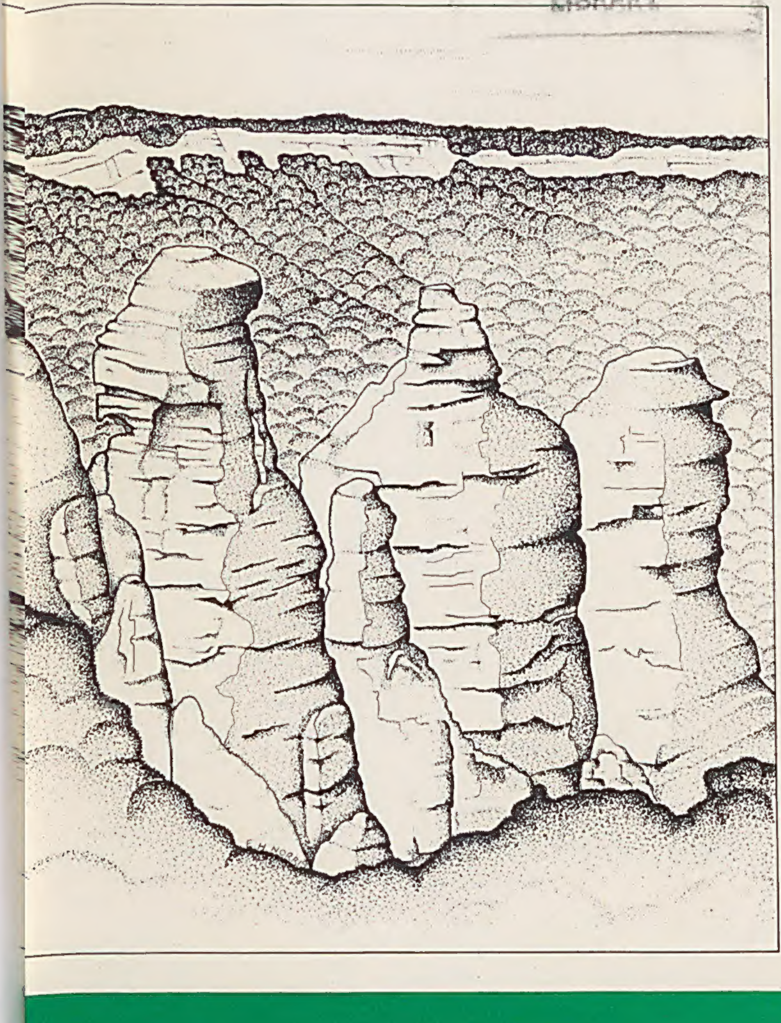

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Ecological contributions from the National Herbarium of New South Wales

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Algae of Carcoar Dam, New South Wales, Australia

V. May

(Accepted for publication 26.2.86)

Abstract

May, V. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1988. Algae of Carcoar Dam, New South Wales, Australia. Cunninghamia 2(1): 1–7. — This paper presents the results of a study of the algae of Carcoar Dam, New South Wales, Australia.

Introduction

An algal study was undertaken of Carcoar Dam (33°37′S, 149°12′E) on the Belubula River near Bathurst in the southern Central Tablelands from September 1977 to February 1981, which included a period of drought (1980–81). Inflow from the River provides high levels of nutrients from an abattoir and a sewage treatment works. Frequently the dam water appears green because of its high algal content and livestock deaths have been recorded, apparently due to toxic algae. Five stations were sampled, four in Carcoar Dam and one immediately upstream (Figure 1), at 2–4 week intervals. Methods are fully described in May & Powell (1986) from work on Chaffey Dam. A full data set, including tabular and graphic analysis, is lodged with the Library, Royal Botanic Gardens, Sydney.

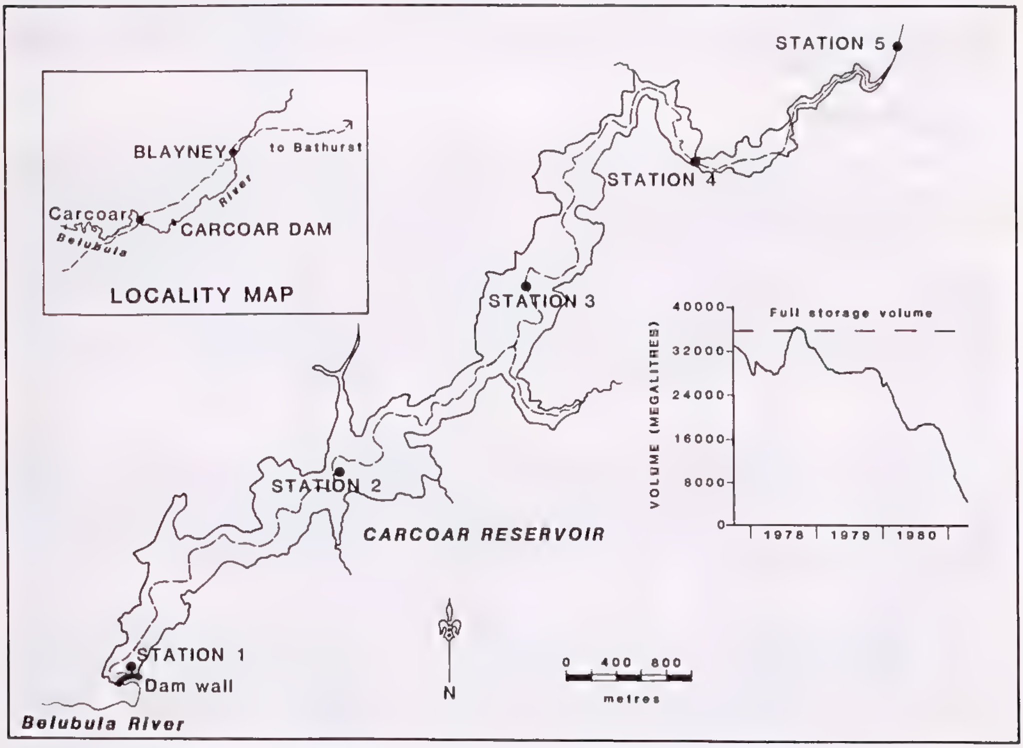

Figure 1. Location of Carcoar Dam and the Belubula River showing collecting stations and the volume stored in the dam over the study period.

Results and discussion

Sixty-one algal taxa[1] were recorded; 33 were common (frequency >5%), 24 were rare (frequency ≤5%) and four were found only as drift material (Table 1, Status). The common taxa are the chief indicators of changing conditions within the Dam; the rare species are of far less importance, but often reinforce the patterns shown by the common taxa.

Belubula River station

The Belubula River station (station 5) differed in many ways from the four dam stations, with many different species showing lower or higher frequency or abundance ratings (Table 1, Distribution Between Stations). The common taxa were present throughout the year but showed increased frequencies from late winter to summer and high abundance usually between October and November.

Seasonal growth

There were relatively fewer differences in persistence or abundance between the four dam stations than between the dam stations and the river station, with 12 of the 33 common taxa being found at all four stations within the dam in each of the first three years and at stations 1 to 3 in the fourth year (during drought) (Table 1, Persistence). Most of these occurred at any time of the year, but often were more common during summer (Table 1, Annual Distribution). Other species were less evenly distributed, appeared later in the year and usually were less common. Only *Anabaina*, *Anacystis* and *Melosira granulata* showed medium or high abundance ratings each year at all dam stations (Table 1, Abundance); *Sphaerocystis* showed a similar pattern except during the drought. Most taxa were more common in summer, but the greatest total biomass occurred later, between February and April, due largely to the very heavy growth of the blue-green algae *Anacystis* and *Anabaina*.

Depth of station

Most taxa flourished at or near the surface (top 0.5 m) rather than at lower depths. More frequent in bottom collections, however, were *Melosira granulata*, *Schizothrix*, *Staurastrum* and usually *Cyclotella* (Table 1, Vertical Distribution).

High and very high abundance ratings were recorded only in surface collections for *Anabaina* and *Anacystis* (and usually also *Sphaerocystis*), while *Melosira granulata* and *Staurastrum* became abundant or very abundant either in surface collections or equally in surface and bottom collections. Very similar results were reported for Chaffey Dam by May and Powell (1986).

Drought

From the onset of drought (February 1980), the common taxa showed differing responses: as increased or reduced frequency, slightly earlier seasonal appearance, wider distribution or greater abundance (Table 1, Drought). In addition, 12 taxa were found only during the drought period, though all were rare.

Nutrients

Stratification of the dam water occurred to a varying degree each summer (data supplied by Water Resources Commission). The associated anoxia and high nutrient levels in the bottom water, combined with adequate light penetration,

---

[1] Where only one species of a genus is reported, the generic name alone is used. A full list of species names and authorities is given in Table 1.

Table 1: Species recorded from Carcoar Dam and Belubula River, together with information about their occurrence related to the position of stations, depth of water, and drought.

Taxon	1 Status	2 Dist. b. Stns.	3 Persistence	4 Annual Dist.	5 Abund.	6 Vert. Dist.	7 Drought
Actinastrum hantzschii Lag.	C	I	—	Jan–Mar	1	—	—
Agmenellum thermale (Kuetz.) Drouet & Daily	R	—	—	—	—	—	—
Anabaina circinalis Rabenh.	C	I	x	Jan	2	Ss	M
Anacystis cyanea *(Kuetz.) Drouet & Daily *(Microcystis aeruginosa Kuetz.)*	C	I	x	Feb	2	Ss	—
Ankistrodesmus falcatus (Corda) Ralfs	C	I	x	Sept	1	S	L
Aphanizomenon (ecophene of *Calothrix parietina* (Naeg.) Thuret)	R	—	—	—	—	—	—
Botryococcus braunii Kuetz.	C	L	x	Nov	1	S	M
Ceratium hirundinella (O. F. Muell.) Dujardin	R	—	—	—	—	—	x
Chlamydomonas sp.	R	—	—	—	—	—	x
Cladophora sp.	D	—	—	—	—	—	—
Closterium aciculare T. West	C	L	—	Feb–Mar	1	—	M
C. acutum (Lyngb.) de Bréb.	C	I	—	Apr	2	—	M
C. parvulum Naeg.	C	F	—	Jan	—	—	—
C. sp. 1	C	F	—	Jun, Dec	—	—	—
Crucigenia rectangularis (A. Braun) Gay	R	—	—	—	—	—	—
Cyclotella meneghiniana Kuetz.	C	—	x	Jan–Sept	2	B	—
Diatoms (undetermined species)	C	—	x	Dec–Jan	2	—	M
Dictyosphaerium pulchellum Wood	R	—	—	—	—	—	—
Eudorina elegans Ehrenb.	R	—	—	—	—	—	—
Euglena acus Ehrenb.	C	F	—	Jan, Aug	—	—	—
E. polymorpha Dang.	C	I	—	Feb	2	—	—
E. sp. aff. *tripteris* (Dujardin) Klebs	R	—	—	—	—	—	x
E. sp. 1	R	—	—	—	—	—	x
Glenodinium sp.	R	—	—	—	—	—	—
Gonium pectorale Muell.	R	—	—	—	—	—	—
Melosira granulata (Ehrenb.) Ralfs	C	I	x	Sept	2	B	—

Taxon	1 Status	2 Dist. b. Stns.	3 Persist- ence	4 Annual Dist.	5 Abund.	6 Vert. Dist.	7 Drought
M. varians Ag.	C	—	—	Oct–Nov	—	—	L
Micractinium pusillum Fres.	R	—	—	—	—	—	—
Microcoleus lyngbyaceus (Kuetz.) Crouan	C	—	—	Jan–Feb	—	—	M
Oedogonium sp.	D	—	—	—	—	—	—
Oocystis gigas Archer	C	L	—	Feb	1	—	—
O. parva West & West	C	I	x	Dec	1	—	—
Oscillatoria ?lutea Ag.	C	I	—	Dec	—	—	—
Pandorina morum (Muell.) Bory	C	—	—	Jun	—	—	—
Pediastrum boryanum (Turp.) Meneghini	C	F	—	Jan	—	—	—
P. duplex Meyen	C	—	—	Dec	—	—	M
Peridinium granulosum P'fair	R	—	—	—	—	—	x
Phacus caudatus Huebner	C	F	—	Jan	—	—	—
Scenedesmus abundans (Kirchner) Chodat	R	—	—	—	—	—	—
S. bijugus (Turp.) Kuetz.	C	—	—	Jan–Feb	—	—	—
S. obliquus (Turp.) Kuetz.	C	—	—	Dec–Jan	—	—	M
S. quadricaudus (Turp.) de Bréb.	C	F	—	Jan–Feb	—	—	M
Schizothrix calcicola (Ag.) Gomont	C	I	x	Dec	1	B	M
Schroederia judayi G. M. Smith	R	—	—	—	—	—	—
Selenastrum bibranum Reinsch.	R	—	—	—	—	—	x
Sphaerocystis shroeteri Chodat	C	I	x	Oct	2	S	—
Spirogyra sp.	D	—	—	—	—	—	—
Spirulina subsalsa Oersted	R	—	—	—	—	—	x
Staurastrum pingue Teiling	C	I	x	Dec–May	2	B	—
Stigeoclonium sp.	D	—	—	—	—	—	—
Synura adamsii G. M. Smith	C	—	—	Aug	1	—	—
Tetraëdron constrictum G. M. Smith	R	—	—	—	—	—	—
T. limneticum Borge	R	—	—	—	—	—	x
T. regulare Kuetz.	R	—	—	—	—	—	—
T. trigonum (Naeg.) Hansgirg	R	—	—	—	—	—	x

Tetraspora lubrica (Roth) Ag.	R	—	—	—	—	—	x
Trachelomonas armata (Ehrenb.) Stein	C	—	—	Mar–Apr	1	S	M
T. girardiana (P'fair) Deflandre	R	—	—	—	—	—	x
T. hispida (Perty) Stein	C	—	x	Jan	2	S	—
T. sp.	R	—	—	—	—	—	x
Volvox globator L.	C	L	—	Nov	1	—	—

1 Status (all species). C = Common species (>5%). R = Rare species (≤5%). D = Drift species.

2 Distribution between stations (common species). L = Lacustrine species (absent from station 5). I = Intermediate species, not strongly lacustrine or fluvial. F = Fluvial species (abundant only at station 5).

3 Persistence (common species). x = Species that occurred in all four dam stations in each of the first 3 years and in stations 1–3 during drought.

4 Annual Distribution (distribution during the year) (common species). Most common months of occurrence at most stations.

5 Abundance (common species). 1 = Medium abundance rating. 2 = High abundance rating. (Some abundance figures are also mentioned under Distribution Between Stations, Vertical Distribution, and Effect of Drought.)

6 Vertical distribution (common species). S = Frequency usually highest in surface collections. B = Frequency usually highest in bottom collections. s = abundance usually highest in surface collections.

7 Drought (effect of drought). Common species: M = species becoming more common during drought. L = species becoming less common during drought. Rare species: x = species found only during drought (1980–81).

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* *Anacystis* Meneghini (1837) is the oldest name (Drouet & Daily, 1956) available for the genus when it is treated in the broad sense including *Microcystis* Lemmermann (1907). The latter name was conserved (Lanjouw, 1961) against the earlier name *Microcystis* Kuetzing (1833), a Euglenoid genus. The type species for the genus *Anacystis* is *A. marginata* Meneghini (1837) (now = *A. montana* (Lightft.) Dr. & Daily), while the type species for the segregate genus *Microcystis* is *M. aeruginosa* (Kuetzing) Kuetzing (1848). The name of the latter species, when treated as *Anacystis*, is *A. cyanea* (Kuetzing) Drouet & Daily (1952), the name *A. aeruginosa* being already in use for a different species, *A. aeruginosa* (Zanardini) Drouet & Daily (1948).

stimulated intensive growth each year of *Anacystis* and *Anabaina*, both potentially toxic Cyanophytes. A larger biomass, indicated by higher chlorophyll *a* readings in surface water, developed when more definite stratification occurred. The very dense surface growth of blue-green algae at Station 4 parallels the results found in Burrinjuck Dam (May 1978), showing that these algae occur most often in regions just below the entry of nutrient-rich rivers into the dam. Thus, the stratification and bottom water nutrient concentration appear to control the total biomass of blue-green algae produced, but it appears to be the condition of the surface water that determines the dominant species.

Relative occurrence of *Anacystis* and *Anabaina*

It seems likely that it is changes in the conditions in the surface water, in particular changes in the concentration of available nitrogen (NO_x), that determine which of the Cyanophyte pair of species becomes dominant, the nitrogen-fixing *Anabaina* flourishing better than the non-nitrogen-fixing *Anacystis* when there is a lower NO_x concentration (see Fitzgerald, 1969). It appears that, with lower concentrations of NO_x, *Anabaina* is stimulated to fix its own atmospheric nitrogen and so can continue dense growth, provided that phosphorus is available; meantime the growth of *Anacystis* is restricted by the nitrogen shortage.

Later in the season, after April, possibly due to a drop in temperature, a reduction of biomass (and hence more available nitrogen) appears to be associated with the disappearance of *Anabaina*; some nitrogen will be recycled from the decomposition of *Anabaina* and this will further aid the growth of *Anacystis*. Ganf (1980) and Ashton (1979) have found temperature changes to be important in controlling shifts in species composition.

Comparison with other dams

The overall composition of the phytoplankton of Carcoar Dam is compared with that of other Australian Dams in Table 2. Since 1909, when the study of Yan Yean was carried out, the general incidence of blooms of Cyanophyte algae has increased (Carmichael 1981), as occurs at Carcoar and in numerous other reports. This demonstrates a drift from predominantly Chlorophycean-dominated clean water to a more enriched (polluted) water dominated by Cyanophytes with or without associated Euglenophytes.

Control measures

Traditionally, control of unwanted algae is by chemical means, by limiting the supply of nitrogen, phosphorus or both in the water (usually this comes from point sources). In Carcoar Dam at least, the practical method of controlling the excessive growth of blue-green algae is to reduce the level of phosphorus in the water, since a reduction in nitrogen is offset by extra nitrogen-fixing by *Anabaina*.

If the effects of stratification are reduced (by aerating the hypolimnion or by using artificial circulation to mix the whole water column), particularly early in the season, this could also limit the growth of blue-green algae (Pastorok *et al.* 1980).

Acknowledgements

These studies were carried out as part of the continuous study of water quality in New South Wales storages being undertaken by the Water Resources Commission of New South Wales. I am indebted to the Commission for making the water collections available to me and for other valued assistance. I also wish to thank Mr Andrew Mitchell and Dr Jocelyn Powell for their editorial comments.

Table 2: Comparison of phytoplankton composition at various Australian dams
(A = number of species; B = number of abundant genera).

	Carcoar (May, 1988)		**Chaffey** (May & Powell, 1986)		**Burrinjuck** (May, 1978)		**Yan Yean** (West, 1909)
Algal class	A	B	A	B	A	B	B
Chlorophyta	36 (59)*	4 (36)	25 (52)	8 (53)	21 (65)	88 (77)	8 (80)
Chrysophyta	5+ (8)	3 (27)	5+(10)	3 (20)	4+(13)	22 (19)	2 (20)
Cyanophyta	8 (13)	2 (18)	6 (13)	2 (13)	4 (13)	4 (3)	0 (0)
Euglenophyta	9 (15)	2†(18)	10 (21)	1 (7)	2 (6)	0 (0)	0 (0)
Pyrrhophyta	3 (5)	0 (0)	2 (4)	1 (7)	1 (3)	1 (1)	0 (0)
TOTAL	61	11	48	15	32	115	10

* Percentages in brackets
+ Understated as unidentified species grouped as 'Diatoms'
† Only at station 5

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Acacia dry scrub communities in the Byadbo area of the Snowy Mountains

K. A. Clayton-Greene and D. J. Wimbush

(Accepted for publication 27.5.1986)

Abstract

Clayton-Greene[1], *K.A. and Wimbush*[2], *D.J. (*[1]*Horticultural Research Institute, P.O. Box 174, Ferntree Gully, Australia 3156;* [2]*CSIRO Division of Plant Industry, Canberra, Australia 2601) 1988. Acacia dry scrub communities in the Byadbo area of the Snowy Mountains. Cunninghamia 2(1): 9–24.* — Acacia dry scrubs of the Byadbo area of the Kosciusko National Park and of the adjacent Cobberas-Tingaringy and Snowy River National Parks are mapped. Descriptions of eleven representative sites reveal that the scrubs are dominated by stands of *Acacia* spp. (usually *A. silvestris*) and *Eriostemon trachyphyllus*. These scrubs are virtually restricted to outcrops of sedimentary rocks and rhyodacites. Population studies indicate that these scrubs are perpetuated by occasional intense fires.

Introduction

Closed scrub communities (*sensu* Specht, 1970) are scattered throughout the mountainous Byadbo* area, mostly east of the Snowy River, near the New South Wales–Victoria border (Figure 1), at altitudes typically between 700–1100 m. These communities, hereafter referred to as dry scrubs, are dominated by *Acacia* spp. and known locally as 'black jungle' or 'black scrubs'. The local names are derived from the dark colour and impenetrability of the scrubs contrasting with the surrounding woodland (Figure 2).

The scrubs in the Byadbo area were included by Costin (1954) in the *Acacia binervia* (*glaucescens*)–*Eriostemon trachyphyllus* alliance from the lower Maclaughlin River escarpments. However, in the Monaro region *Acacia binervia* appears to be confined to a small area of scrub near the confluence of the Snowy, Maclaughlin and Delegate Rivers, and has not yet been recorded within the Kosciusko National Park. Nevertheless, many of the other species of Costin's alliance are present in the dry scrubs of the Byadbo area. The Byadbo scrubs also parallel those of the lower Maclaughlin by having an overstorey and understorey dominated respectively by monospecific stands of *Acacia* spp. and *Eriostemon trachyphyllus*.

There is little known about the botany or ecology of these dry scrubs. Forbes, Walsh & Gullen (1982) list the species occurring at eleven sites in Victoria on rocky escarpments of the Snowy River Valley. They call the vegetation 'rocky outcrop open scrubland' and it clearly includes the type of communities described by us as dry scrub. Six of the sites described by Forbes *et al.* contained both *A. silvestris* and *E. trachyphyllus*, one contained *A. falciformis* and *E. trachyphyllus* and two contained *E. trachyphyllus* but no *Acacia* spp.

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* Although local usage refers only to the area east of the Snowy River and north of the Victorian border as the Byadbo, we have for convenience extended the area to include all that shown in Figure 1 populated by dry scrubs.

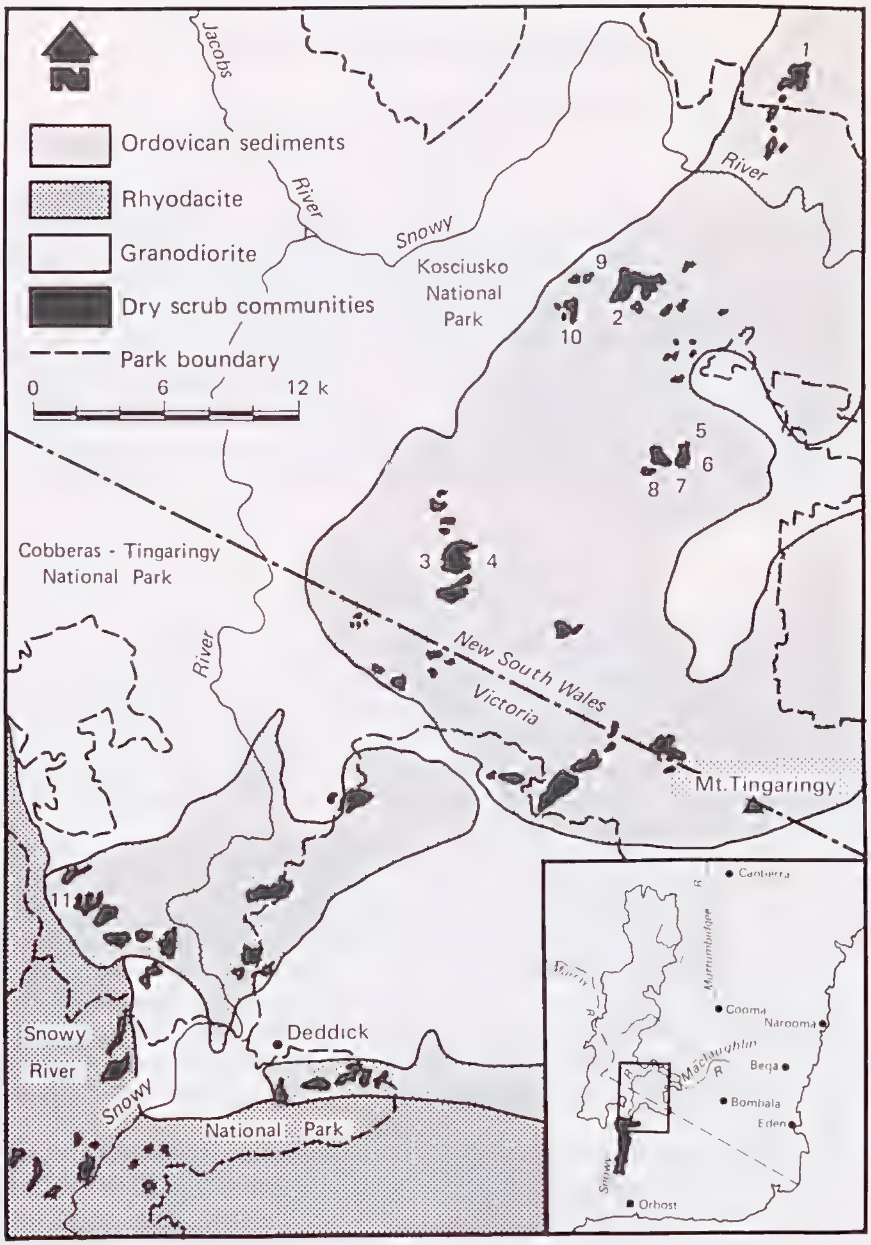

Figure 1. Distribution map of dry scrubs in the Byadbo region of the Snowy Mountains, showing their dependence on geological formation. The geology is not mapped for areas of New South Wales west of the Snowy River. Shaded areas on the inset map are, from north to south: Kosciusko National Park; existing and proposed Cobberas-Tingaringy National Park, existing and proposed Snowy River National Park.

The aim of the present study was to describe the Byadbo dry scrubs, compare them with similar scrubs elsewhere and to elucidate the processes involved in their origin and maintenance. Results would also help in formulating a management strategy for the dry scrubs of Kosciusko National Park (A. Davies, Senior Ranger, pers. comm.).

The study area

Most of the study area (Figure 1) lies within the boundary of the Kosciusko National Park (New South Wales) and the adjacent Cobberas-Tingaringy and Snowy River National Parks (Victoria). Since being explored by Robinson in 1844 (Mackaness, 1941), the area has had a history of cattle grazing, burning, and severe rabbit infestation (Costin, 1954; Clayton-Greene, 1977). Feral horses are also common, and a small feral goat population has persisted in one locality but has not increased. In recent years a system of ridgetop four-wheel drive access tracks has been established.

Climate

The entire study area is in a rain shadow protected from nearly all quarters by high mountains: the Wulgulmerang Tableland and Stradbroke Range in the south-west, the Great Dividing Range to the west and north-west, and areas of extensive upland in the south (for example Mount Tingaringy), south-east and east. Most rainfall comes from easterly airstreams which bring in moist air from the Tasman Sea.

Climatic data for the area are sparse due to the lack of settlement. Mean annual rainfall decreases in a north-easterly direction and much of the area receives around 600 mm per annum (Costin, 1954). There is a slight summer rainfall maximum, for example at Deddick (Figure 1), 67% of annual rainfall occurs between October and March.

Costin (*loc. cit.*) estimated a mean monthly temperature of 21°C in midsummer and 4°C in midwinter for areas occupied by the *A. binervia–E. trachyphyllus* alliance, and these would be comparable to the Byadbo dry scrub areas. Light snowfalls occur, but the snow does not persist. Ground frosts are common in winter, but would be less severe on the higher areas occupied by dry scrubs than on the valley floors. In summer, temperatures on the north-western aspects may reach the high thirties.

Topography, Geology and Soils

Dry scrubs occur on steep and often rocky slopes and are virtually restricted to the large areas of Upper Ordovician siltstones, schists, slates, shales and claystones which extend in a broad belt from north-east to south-west across the area (Figure 1). In the southern part, dry scrubs also occur on Lower Devonian rhyodacites. Only two small scrubs have been mapped from aerial photographs on the coarser-grained granite or granodiorite. However, because of their inaccessibility this has not been field verified. These two scrubs are adjacent to areas of rhyodacite (Figure 1) and it is possible that they are on outliers. Soils were classified by Costin (1954) as lithosols, grey-brown podzolics and colluvial brown earths.

Vegetation of the Byadbo area

The vegetation throughout the area where these dry scrubs occur is a mosaic of woodland and open-forest communities (*sensu* Specht, 1970). Below 600 m elevation, in the Snowy River valley, *Callitris columellaris* and *Eucalyptus albens* form a woodland, with the latter usually extending to altitudes well above the *C. columellaris*. Above 600–700 m, especially on southerly aspects and at lower elevations along water courses, *E. melliodora* and *E. bridgesiana* form woodlands. On the more exposed north- and west-facing slopes, above the *E. albens* communities, *E. goniocalyx* is perhaps the most widespread species with *E. nortonii*, *E. dives*, and *E. macrorhyncha* also common. The latter is particularly common on the patches of shale which occur throughout the region. Open-forest of *E. viminalis*, *E. rubida* and *E. mannifera* subsp. *maculosa* occurs on more sheltered east- and south-facing slopes. On the higher peaks, *E. pauciflora* subsp. *pauciflora*, *E. dalrympleana* and *E. radiata* form open-forest and tall open-forest.

Within these communities the dry scrubs form discrete patches, usually on north- and west-facing aspects, with abrupt boundaries between them and adjacent communities. The upper boundary often coincides with the crest of a ridge. When viewed from above, the outline of dry scrubs is very reminiscent of the pattern of burn produced by wildfires (Figures 1, 2).

Site descriptions

The canopy species that was dominant in both size and number in nine of the eleven dry scrubs was *Acacia silvestris*. In some scrubs there were scattered emergent *Exocarpos cupressiformis*. Depauperate *Eucalyptus nortonii*, *E. albens*, *E. melliodora* and *E. macrorhyncha* occurred singly or in combination both within and emergent above the canopy. *Eriostemon trachyphyllus* was common (usually the main species) in the understorey of every scrub site visited. *Olearia phlogopappa* was also common in the understorey.

Where the canopy of *A. silvestris* was more open, as in older scrubs or near the scrub–woodland boundary there were often shrubs of *Phebalium lamprophyllum*, *Platysace lanceolata*, *Helichrysum conditum*, *H. obcordatum*, *Polyscias* sp. and *Olearia iodochroa*. *Cassytha glabella* often formed a dense tangle over the smaller trees and shrubs. Herbaceous ground cover was minimal in all the scrubs visited.

Only two of the eleven scrubs examined (sites 9 and 10, Figure 2) did not contain *A. silvestris* (Table 1). At site 9 the only *Acacia* species present was *A. kettlewelliae* which is widespread in the region, particularly around other scrubs and on outcrops of shale. Together with *Eriostemon trachyphyllus* and *Daviesia mimosoides*, this species formed a discontinuous shrub layer about 3 m tall. Beneath this was an almost continuous stratum of shrubs of various species, including *Platysace lanceolata*, *Dodonaea viscosa*, *Phebalium lamprophyllum* and *Prostanthera phylicifolia*. The latter species has not been recorded elsewhere in the Byadbo area except in heaths on Mt Tingaringy (Figure 1). Small trees of *Exocarpos cupressiformis* and *Eucalyptus melliodora*, the latter showing extensive defoliation and vertical splits in the bark, were scattered emergents. At site 9 both root suckering and seedling growth of *Eriostemon trachyphyllus* were observed and there were many seedlings of *A. kettlewelliae*.

At site 10 the dominant species was *A. falciformis* growing as a small tree up to 8 m in height and forming an open canopy above a dense understorey of large old shrubs of *E. trachyphyllus* and scattered *O. phlogopappa*. *Callistemon pallidus* was growing on rock outcrops within this scrub. On adjacent slopes *A. falciformis* formed a continuous canopy with very little understorey and the rockiest sites were occupied by *Allocasuarina verticillata*.

At site 2 on areas of outcropping rock there were patches of tall *Acacia doratoxylon* within the typical *A. silvestris* canopy.

Table 1: General site data

Site Location No.	1:100 000 grid ref.	Slope (Deg.)	Aspect	Dominant *Acacia* species
1 Paupong	8626 509351	20	NW	*A. silvestris*
2 Black Jack	8626 427281	26	NW	*A. silvestris–A. doratoxylon*
3 Monument (a)	8626 351156	26	NE	*A. silvestris*
4 Monument (b)	8626 358158	16	W	*A. silvestris*
5 Merambago (a)	8626 462207	19	NW	*A. silvestris*
6 Merambago (b)	8626 457204	20	ENE	*A. silvestris*
7 Merambago (c)	8626 451204	20	NNE	*A. silvestris*
8 Merambago (d)	8626 449205	28	N	*A. silvestris*
9 Slaughter-house (a)	8626 417292	21	NW	*A. kettlewelliae*
10 Slaughter-house (b)	8626 408277	27	NW	*A. falciformis*
11 Wulgulmerang	8523 182995	15	NW	*A. silvestris*

The general appearance of most of the *Acacia* stands in these dry scrubs was one of uniformity, with closed canopies and stems of similar height and size. Closer examination showed that though most stems were of a similar height, there was a range of stem diameters, with occasional individuals much larger than the rest. These larger individuals were often near the periphery of the scrub. Sometimes there were several stands within a scrub, each of relatively uniform structure but clearly distinguishable from each other (Figure 3). All of the scrubs except that at site 9 showed signs of having been burnt (for example butt scars, charcoal, and standing dead trunks, especially of eucalypts).

Methods

The distribution of dry scrubs throughout the Byadbo area was mapped by plotting from aerial photographs onto 1:100 000 maps (Figure 1). During the field work a further two small scrubs were located which were not apparent on aerial photographs. Seventy-three scrubs are thus mapped in Figure 1; however, because access was difficult only eleven were visited (Figure 1 and Table 1), although several more were observed from ground vantage points and helicopter using high-powered binoculars. This enabled a confident identification of the major canopy species (*A. silvestris*).

Stand structure and dynamics were investigated at sites 2–8 (Figure 1, Table 1), using belt transects 2 m wide and 10 m, 25 m or 100 m long, depending on stand density, shorter transects being used in high densities. Within each transect stem density and diameter at height 0.2 m for both living and dead stems of *A. silvestris* and *E. trachyphyllus* were recorded. At sites 2–5, 7, 8 and 11, cross-sections of stems from the main scrub species were taken for ring counting. Those from site 8 were also checked in the Tasmanian Regional Laboratory of CSIRO Division of Forest Research.

At site 1 a line of 5 circular permanent plots each of 0.01 ha was established in May 1975. The centres of the plots were marked by steel posts spaced 25 m apart. All individual trees and shrubs (both live and dead) were counted in three height classes. Measurements were repeated in September 1982.

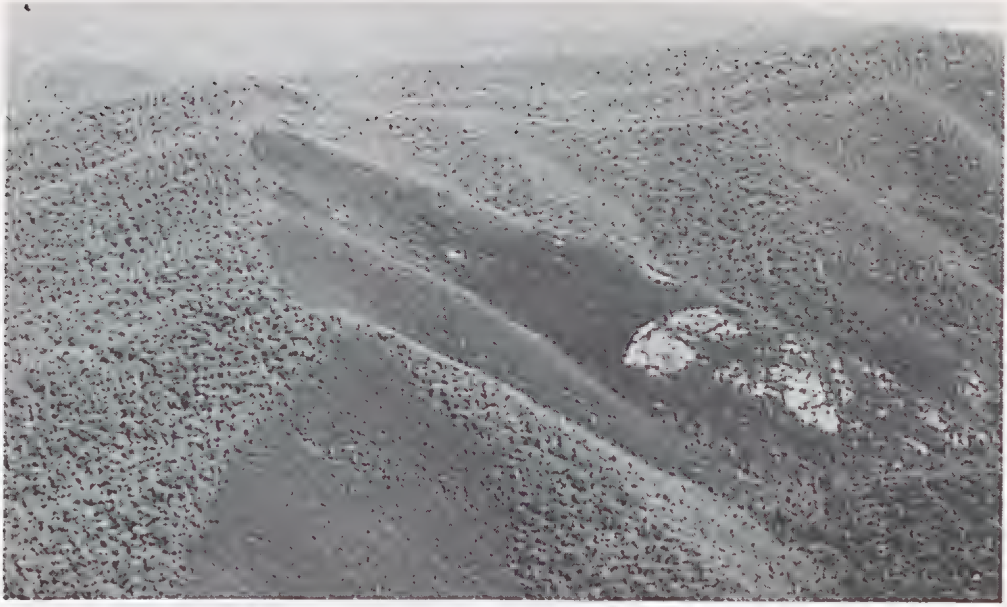

Figure 2. Oblique aerial photograph of *Acacia silvestris–Eriostemon trachyphyllus* dry scrubs at Byadbo, showing their fine texture and dark colour contrasting with the surrounding woodland.

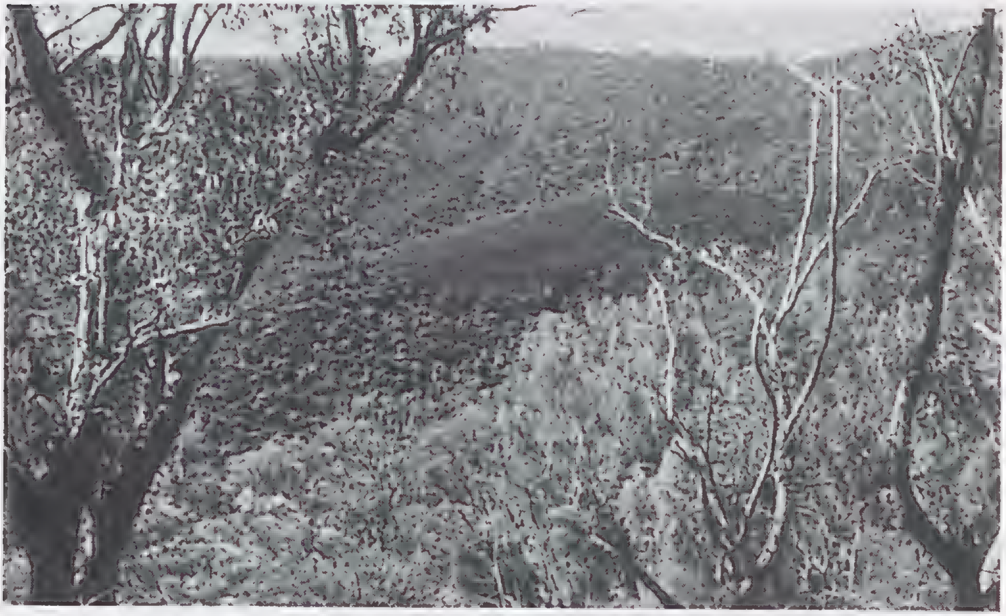

Figure 3. A view looking east over site 3 (obscured) and onto site 4 (cf. Figure 2) which was located near the upper edge of the denser patch of scrub near the centre of the photograph. Immediately below and to the left of this patch is the much older stand which includes site 3, in which the canopies are, unlike the younger ones, rounded in shape and in blossom. The vegetation in the foreground and background is mainly woodland of *Eucalyptus goniocalyx*.

Results

Stem density, basal area and size class distribution

Total live stem densities ranged from 7200 up to 68 000 per hectare (Table 2). Although stems of *E. trachyphyllus* were usually more numerous because of its multistemmed habit, *A. silvestris*, with one exception, had a higher total basal area (Table 2). Total basal area, of which *A. silvestris* comprised up to 88%, ranged from about 9 up to 42 m^2 per hectare. Basal areas were generally similar to those in the surrounding woodland (Clayton-Greene, 1981).

The diameter size-class distributions (Figure 4) showed a similarity in form both between sites and species. As in even-aged stands of *Eucalyptus regnans* F. Muell. (Ashton, 1976), they tended to conform to a normal curve, with the accumulation of suppressed individuals causing a positive skew or bimodal distribution in the younger stands. The modal size class differed widely both between sites and species. At any one site, most stems of *E. trachyphyllus* were smaller than those of *A. silvestris.*

Except at site 2, 20–30% of the total number of *Acacia* stems were dead, (Table 2) whilst the figure for *Eriostemon* was much lower (10%). At each site the size class distribution of dead stems was similar to that for living stems but these stems were on average smaller. This indicates that the stands were thinning out only gradually. Site 2 appears to be a particularly harsh environment characterized by the total basal area (8.82 m^2/ha), the high percentage of dead *Acacia* stems (50%) and the presence nearby of *A. doratoxylon.* In the Byadbo area *A. doratoxylon* typically grows in skeletal soils on rocky outcrops. Surrounding site 2 the vegetation was very open with large senescing *A. doratoxylon* (up to 8 m tall) many of which had old fire scars at their base. Underneath these trees were many small *Acacia* seedlings (less than 10 cm high) which had recently germinated in the absence of fire.

Table 2: Stem density (no. ha^{-1}) and basal area (m^2 ha^{-1}) of living stems of *Acacia silvestris* and *Eriostemon trachyphyllus* and number of dead *Acacia* stems as a percentage of the total, in seven dry scrub sites.

Site	*A. silvestris*	Density (stems ha^{-1}) *E. trachyphyllus*	Total	Dead *Acacia* stems (% of total no. of *Acacia*)
8	31,000	37,000	68,000	23
7	30,500	14,000	44,500	n.a.
6	12,000	10,500	22,500	22
4	7,750	23,750	31,500	28
2	4,916	7,830	12,746	50
5	4,100	5,500	9,600	22
3	950	6,250	7,200	21

Site	*A. silvestris*	Basal Area (m^2 ha^{-1}) *E. trachyphyllus*	Total	% *Acacia*
8	13.76	3.11	16.87	82
7	11.86	1.93	13.79	86
6	14.99	2.06	17.05	76
4	16.08	10.19	26.27	61
2	5.69	3.13	8.82	65
5	16.32	5.17	21.24	88
3	17.76	24.42	42.18	42

Ring counts

Ring counts obtained by the CSIRO Division of Forest Research in Tasmania and those obtained by the authors on the same stems were similar. At low magnification, there appeared to be distinct rings in the cross-sections from both *Acacia silvestris* and *Eriostemon trachyphyllus*. However, these rings were less well-defined at higher magnification, and in *Eriostemon* there was a strong tendency for narrow and wide rings to alternate, indicating perhaps a pause in cambial activity associated with flowering (T. Bird, pers. comm.). In the oldest trees, heart rot often made ring counting difficult.

At some localities, there were a few large stems of *Acacia silvestris* (Figure 4, Table 3) which had fire scars and were probably survivors of an older generation. Given the difficulties of accurate ring counting, and the probable failure of suppressed stems to produce rings in some years, most stems in three of the scrubs that were sampled intensively (sites 2, 7 and 11) appeared to be between 25 and 35 years old.

Aerial photographs taken in 1964 show that the scrub at site 8 had been recently defoliated by what must have been an intense fire that left clearly defined patches of scrub with unburnt canopies on or near the crests of ridges. Ring counts at site 8 confirmed the date of this fire. Furthermore, two of the *Eriostemon* stem sections from within the adjacent undefoliated ridgetop scrub at site 7, (with ring counts of 31 and 34), had 20 year-old scars. This indicates that the fire in 1964 penetrated the understorey but did not kill the vegetation at site 7.

The oldest *A. silvestris* stem sampled was 200 mm diameter and had approximately 120 rings, and the oldest *E. trachyphyllus* was 60 mm diameter with 72 rings (Table 3). In both instances they were much larger and older than surrounding trees and had survived or escaped fires. There was a fire scar at the base of the *A. silvestris*. Stems of *E. trachyphyllus* up to 200 mm diameter were observed, but not sampled.

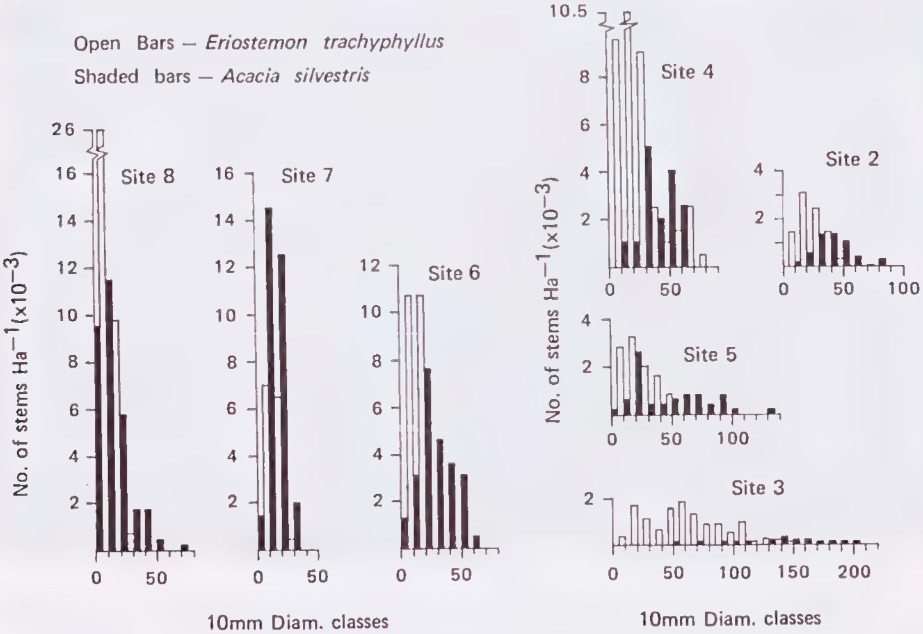

Figure 4. Size class distribution in 10 mm diameter classes of *Acacia silvestris* and *Eriostemon trachyphyllus* at sites 2–8.

Table 3: Ring counts and overbark diameters of fresh stems of *Acacia silvestris* and *Eriostemon trachyphyllus* from seven dry scrub sites.

	A. silvestris		*E. trachyphyllus*	
Site No.	Diameter (mm)	Ring count	Diameter (mm)	Ring count
2	200	120	40	42
	94	40	29	42
	89	37	29	41
	87	41	23	34
	55	30	15	30
	54	27	10	27
	45	35	9	26
	42	35	14	27
	39	30		
	38	26		
	37	27		
	34	29		
	32	29		
	32	29		
	29	21		
	27	30		
3	49	41		
4	50	42		
	46	26		
5	105	46	60	72
	44	30	20	39
7	68	34	46	32
	64	31	38	24
	39	27	37	36
	38	27	30	31
	30	26	20	34
	27	26	9	22
	26	29		
	20	22		
	19	31		
	10	12		
8	53	19	20	23
	28	19	19	17
	27	19	16	25
	21	21	8	17
	16	17	8	16
	13	17	5	10
	13	16		
	8	15		
11	56	27	16	20
	49	26	14	20
	35	26		
	21	19		

Permanent plots

The results from the permanent plots (Table 4) show a decrease in all height classes of *A. silvestris* and a reduction since 1975 in the percentage of seedlings occupying the smallest height class. *Eriostemon trachyphyllus* shows a similar reduction in the smallest height class, but numbers in the >1.0 m class remained similar over time. Of the *Olearia* spp. only *O. iodochroa* showed an increase in numbers in the smallest height class, but this species was present on only one of the five plots. The number of plots was insufficient to produce statistically significant trends.

Table 4: Mean no. of live stems/ha of four woody species in three height classes at site 1 (Paupong) in 1975 and 1982. Data summarised from 5 permanent 0.01 ha circular plots. Standard errors of the mean are shown in brackets.

	Year	**Height Class (m)** <0.3	 0.3–1.0	 >1.0	**Mean no. stems per ha**
Acacia silvestris	1975	180	60	3580	3820 (433)
	1982	20	40	2520	2580 (266)
Eriostemon trachyphyllus	1975	540	80	620	1240 (230)
	1985	360	100	640	1100 (286)
Olearia phlogopappa	1975	120	80	0	200 (68)
	1982	100	40	0	140 (30)
Olearia iodochroa	1975	440	100	60	600 (232)
	1982	620	60	100	780 (338)

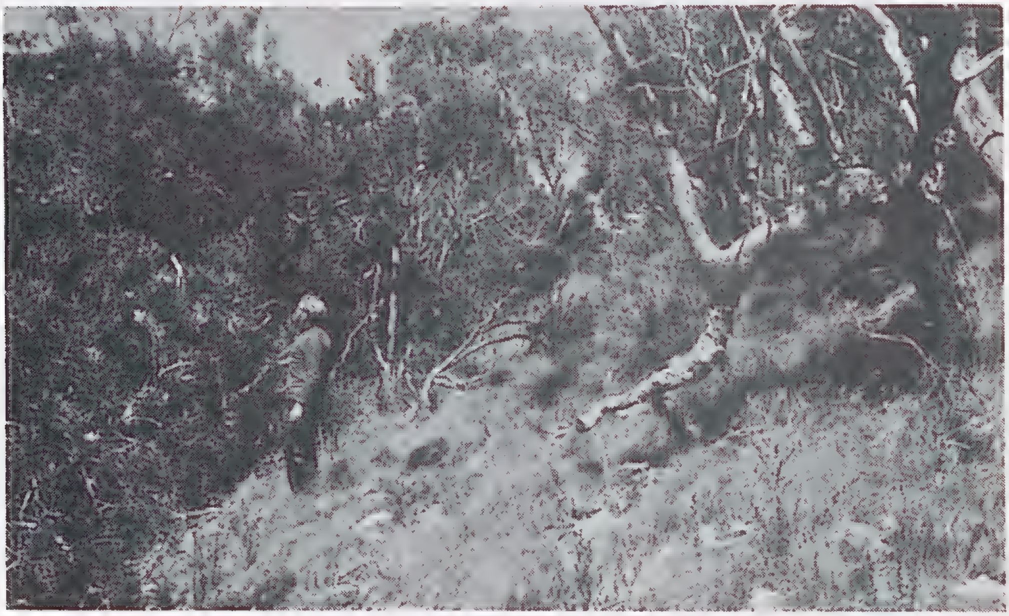

Figure 5. The upper south-western edge of the 'Monument' scrub (site 3) showing the abrupt boundary with *Eucalyptus goniocalyx* woodland on the right.

Discussion

It is clear from Figure 1 and field survey that within the Byadbo region the occurrence of these scrubs is related to lithology and aspect. Scrubs are predominantly found on north or north-west aspects and only two appear to occur on the coarse-grained soils derived from granodiorite. Another striking feature is the abrupt boundary between scrub and surrounding woodland (Figures 2, 5), there being virtually no ecotone.

Soil type, angle of slope and aspect do not appear to be critical in determining the lateral or lower boundaries of these scrubs. The boundaries often extended diagonally across slopes uniform in these attributes. However, upper boundaries normally coincided with a ridge crest. Only on a few wetter slopes with an easterly aspect (for example near site 3) were there mixtures of scrub and woodland species. A few small seedlings of *A. silvestris* were seen growing among *Chionochloa pallida* tussocks in woodland bordering the scrub. Similarly on the rocky summits of the Ballantyne Hills in the higher rainfall area near the Stradbroke Range, *Eriostemon trachyphyllus*, *Phebalium lamprophyllum*, *Dodonaea viscosa* and other typical scrub species form an understorey beneath an open canopy of *Eucalyptus dives* and *E. rubida*. In this community *A. silvestris* is absent.

Within each scrub the population is either approximately even-aged (for example site 8) or discontinuous with large gaps between ages (for example site 2). An occasional instance of suckering was observed, however most regeneration had clearly been from seed. At all sites there were few if any seedlings. The permanent plots also show no evidence of further recruitment by the main canopy species after initial establishment (Table 4). It is thus evident that each population originated from an event that killed most of the standing vegetation and resulted in seed of both *Acacia* and *Eriostemon* germinating in large numbers.

Though it is possible that the rare extreme drought or intensely cold interval could kill large areas of scrub, these would be unlikely to produce the clear boundaries that are evident between discrete stands of different ages within the one scrub (for example Figure 3). Nearly all sites had abundant evidence of fire and it seems that fire is the likely instrument of regeneration. Evidence for intense fire as the main agent of regeneration also comes from the distribution of the scrubs, the large number of dead and often fire-scarred trees, dead spars, butt-scars on older live trees and the fire history, gleaned from both local knowledge and aerial photographs.

According to local knowledge (J. Rogers pers. comm.), wildfires were widespread in the region in February 1952 and burnt site 11. Ring counts of *A. silvestris* are in accordance with this date although those of *E. trachyphyllus* may indicate a more recent fire. Similarly at site 8 the occurrence of a fire around 1964 is shown on aerial photographs and the ring counts show close agreement. Examination of the ring counts from the other sites indicates that the scrubs at sites 2 and 7 and possibly 4 and 6 also arose after the 1952 fires. Sites 3 and 5 appear to date from an earlier fire. Although the sample size is very small, two episodes of destruction are indicated at site 4 (Table 3 and Figure 3) at 30 and possibly 50 years B.P.

It is reported (J. Rogers, pers. comm.) that under extreme conditions of high temperature and strong wind, fire moves rapidly through the scrubs, but at other times they can be very difficult to burn (Forestry Commission of New South Wales, 1983). Several instances were noted where recent low intensity fires in the surrounding woodland had burnt to the edge of a scrub but failed to penetrate. On one occasion, aerial incendiaries were dropped into scrubs during control burning operations without any resulting ignition. The scrubs will evidently only ignite under hot dry windy conditions, and the fire intensity would then probably be increased by the high oil content of the living *Eriostemon* leaves and other Rutaceous plants.

Reasons for the failure of low-intensity fires to penetrate the scrub can only be speculative. These could include a dense closed canopy, lack of ground vegetation and only a moderate flammability of dead *Acacia* leaves. King & Vines (1969) reported that dried leaves of two other species of *Acacia* (*A. longifolia* var. *sophorae* and *A. maidenii*) were in the mid-range of flammability of species tested due to a relatively high total mineral content. In the dry Byadbo environment, *Acacia* litter is likely to be only slowly mineralized, thus retaining its low flammability.

Only site 9 showed no evidence of fire. This site differed from the other scrubs in being dominated by *A. kettlewelliae*, and there was a continual though sparse regeneration of the *Acacia* and other species. Site 9 was a particularly harsh site with the vegetation showing signs of frequent moisture stress. This vegetation may be an arrested succession due to frequent plant death from drought.

Site quality has a marked effect on the form of these scrubs and this is illustrated by comparing site 2 with site 7 where differences in tree size do not indicate different ages. Both have vegetation of similar age (Table 3), although their size class distributions are quite different (Figure 4). At site 7, where soil, slope and aspect are more favourable, the closed canopy is approximately 6 m in height. Stems are densely packed with the majority being 10–30 mm in diameter. Site 2 is more rocky, with skeletal soils, a steeper slope and more exposed aspect: *Acacia silvestris* is only 4 m tall, with a density <30% and a basal area <65% of those at site 7. However most stems are 30–60 mm in diameter (Figure 4), giving an impression of greater age. At site 2, due to large areas of exposed rock, seedling establishment is restricted to fewer sites. There may also be more soil moisture available at site 2 due to less transpiration. Krause & Kummerow (1977) found that chaparral vegetation in California developed greater moisture stress on a shaded slope than on an adjacent exposed slope. This was attributed to the greater amount of transpiring leaf surface area on the shaded slope. Thus although the overall environment of site 2 is harsher than site 7 individual trees may experience more favourable conditions for growth.

The fate of these scrubs if left unburnt is uncertain and the reasons for their original development can only be speculative. The data from the permanent plots (Table 4) and population structures (Figure 4) suggest that over time *E. trachyphyllus* and particularly *A. silvestris* would decline or disappear (the vegetation on the summits of the Ballantyne Hills may represent such a later seral stage).

A further striking feature of the Byadbo area is that both *A. silvestris* and *E. trachyphyllus* rarely occur in the surrounding woodland. This contrasts with *A. kettlewelliae* and *A. falciformis* which also form scrubs on sites similar to those occupied by *A. silvestris* but are common elsewhere in the area. *A. doratoxylon*, the other scrub-forming species, typically occurs on rock outcrops when not in scrubs.

Near the southern coast of New South Wales, 120 km ENE of the Byadbo area, there is another dry scrub dominated by *A. silvestris* and *E. trachyphyllus*. It is located on a west-facing slope above the Brogo River 3 km west of Mumbulla Mountain, at only 100 m above sea level. The climate is considerably warmer and wetter (875 mm rainfall per annum at Bega) than that of the Byadbo area.

In a recent Environmental Impact Statement (Forestry Commission of New South Wales, 1983), *A. silvestris* is described as being 'reasonably well distributed in Wandella State Forest right to the edge of the tableland . . . but only occasionally forms (these) thickets which exclude all but an occasional eucalypt emergent'. A map shows areas where *A. silvestris* canopy cover is 80% or more, and these are nearly all on north- or west-facing slopes and all on Ordovician metasediments. A comment is made that the 'species . . . is generally too moist to be burnt in hazard reduction burning operations'.

No mention is made in the document of *Eriostemon trachyphyllus* except in the general species list, but in the Silvestris Forest Preserve nearer Narooma it forms a dense understorey beneath small trees of *A. silvestris* (up to 15 m tall) and scattered eucalypts (up to 24 m tall). Similar scrubs have been reported in the Upper Brogo River catchment (M. Parris, Ben Boyd National Park Advisory Committee, pers. comm.), and the *A. binervia–E. trachyphyllus* dry scrub reported by Costin (1954) is located on the lower Maclaughlin River in a habitat intermediate to those on the Snowy and Brogo Rivers. All these scrubs are located on metasediments. The wide range of climate that the scrubs tolerate suggests that climate is not a major factor; soil type and fire regime remain the most likely influences controlling their present distribution.

Closer to the coast, *A. silvestris* is a common species of forest communities and it could be postulated that a dry scrub may develop on a dry slope with skeletal soils in response to frequent hot fires. If this frequency were too high to allow eucalypt regeneration, but not too high to prevent *Acacia* reproducing from seed, the seedlings of the latter may crowd out all other species. Indeed the lower Brogo River scrub was reported to have appeared after an intense wildfire, replacing forest (D. Christopher, New South Wales Forestry Commission, pers. comm.). It is not known whether this fire was the last of a series.

The absence of *A. silvestris* from surrounding vegetation in the Byadbo area suggests that the scrubs have been in existence for a long period. Furthermore, if the Byadbo scrubs had a similar origin to those in other localities, this suggests a much moister climate than exists at present.

Scrubs dominated by *A. silvestris* appear to be much more common and widespread than those dominated by *A. binervia*. It would thus be appropriate to place the *A. binervia–E. trachyphyllus* alliance of Costin (1954) in an association under a new *A. silvestris–E. trachyphyllus* alliance.

Conclusion

The Plan of Management for Kosciusko National Park (1982) includes the 'black scrubs' under 'Outstanding Natural Resources' and lists their protection as an objective of management (Section 1.3.3 of the Plan of Management).

The word 'protection' has many connotations, but if the objective is to maintain scrubs in a variety of age classes, then the plan should recognize that the natural cycle of regeneration of the scrubs almost certainly includes intense fire. It would appear that the only conceivable threat to the continued existence of the scrubs may come from attempts to exclude intense fire by too-frequent low-intensity burns in the surrounding woodland.

We suggest that a more appropriate name for the *Acacia binervia* (*glaucescens*)–*Eriostemon trachyphyllus* alliance of Costin (1954) would be the *A. silvestris–E. trachyphyllus* alliance. *A. silvestris–E. trachyphyllus*, *A. binervia–E. trachyphyllus*, *A. falciformis–E. trachyphyllus* and *A. kettlewelliae–E. trachyphyllus* would be associations within the alliance.

Acknowledgments

The authors wish to thank the members of the Monaro Conservation Society who assisted with the early ground surveys. A special debt is owed to Margaret Parris, who also gathered data on the coastal scrubs, added to the species list and criticized the manuscript. Others who made helpful comments were Drs A.B. Costin, J.H. Leigh, and A.M. Gill and Mr A. Slee. Dr J. Banks checked the ring counts. We are grateful to Mr Trevor Bird of CSIRO Division of Forest Research for examining several stem sections, and estimating their ages. Thanks are also due to Ms Tanya Clayton who prepared the figures and to Ms Susan Kelo who typed the manuscript. The Department of Agriculture, Victoria, made time available, and the staff of the Kosciusko National Park, particularly A. Davies and P. and C. Shady gave valuable assistance in the field. The National Parks and Wildlife Service of New South Wales also provided a helicopter from which Figure 2 was photographed.

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Appendix 1
List of species collected in and around the Byadbo dry scrubs

Species	Within scrubs	Ecotone	Surrounding woodland
PTERIDOPHYTA			
Aspleniaceae			
Asplenium flabellifolium Cav.			X
Pteridaceae			
Cheilanthes tenuifolia Sw.	X	X	X
GYMNOSPERMAE			
Cupressaceae			
Callitris endlicheri (Parl.) F. M. Bailey			X
ANGIOSPERMAE-DICOTYLEDONEAE			
Casuarinaceae			
Allocasuarina verticillata (Lam.) L. Johnson (syn. *Casuarina stricta* Dryand.).	X		
Proteaceae			
Banksia marginata Cav.			X
Persoonia silvatica L. Johnson			X
Santalaceae			
Exocarpos cupressiformis Labill.	X		
Loranthaceae			
Amyema quandang (Lindl.) Tiegh.	X		
Polygonaceae			
Muehlenbeckia diclina (F. Muell.) Druce		X	
Chenopodiaceae			
Einadia hastata (R. Br.) A.J. Scott	X	X	X
Lauraceae			
Cassytha melantha R. Br.	X		
Ranunculaceae			
Clematis microphylla DC.			X
Mimosaceae			
Acacia dealbata Link		X	X
A. deanei (R.T. Baker) Welch *et al.* subsp. *paucijuga* Tind.			X
A. doratoxylon A. Cunn.	X		X
A. falciformis DC.	X	X	X
A. implexa Benth.	X		X
A. kettlewelliae Maiden	X	X	X
A. mearnsii De Wild.		X	X
A. silvestris Tind.	X		
Fabaceae			
Bossiaea buxifolia A. Cunn.			X
Daviesia mimosoides R.Br.	X		X
Glycine clandestina Wendl.			X
Indigofera australis Willd.		X	X
Oxylobium procumbens F. Muell.			X
Pultenaea procumbens A. Cunn.			X
P. juniperina Labill. var. *planifolia* H.B. Williamson			X
Rutaceae			
Crowea exalata F. Muell.		X	X
Eriostemon trachyphyllus F. Muell.	X		
Phebalium lamprophyllum (F. Muell.) Benth.	X	X	
Zieria cytisoides Sm.			X
Sapindaceae			
Dodonaea viscosa Jacq. subsp. *cuneata* J.G. West			X
D. viscosa Jacq. subsp. *spatulata* J.G. West	X	X	X
D. viscosa Jacq. subsp. *cuneata* J.G. West X subsp. *angustissima* J.G. West		X	

Species	Within scrubs	Ecotone	Surrounding woodland
Rhamnaceae			
Cryptandra amara Sm.			X
Pomaderris angustifolia N.A. Wakefield			X
P. ledifolia A. Cunn.			X
P. pallida N.A. Wakefield			X
Myrtaceae			
Callistemon pallidus (Bonpl.) DC.	X		
Eucalyptus albens Benth.	X		X
E. bridgesiana F. Muell.		X	X
E. dives Schau.	X	X	X
E. nortonii (Blakely) L. Johnson	X	X	X
E. macrorhyncha F. Muell. ex Benth.	X	X	X
E. melliodora A. Cunn. ex Schau.		X	X
E. viminalis Labill.		X	X
Leptospermum phylicoides (A. Cunn. ex Schau.) Cheel		X	
Araliaceae			
Polyscias sp. aff. *sambucifolia*	X	X	X
Apiaceae			
Platysace lanceolata (Labill.) Norman		X	
Epacridaceae			
Astroloma humifusum (Cav.) R.Br.			X
Lissanthe strigosa (Sm.) R.Br.		X	X
Melichrus urceolatus R.Br.			X
Monotoca scoparia (Sm.) R.Br.			X
Lamiaceae			
Prostanthera phylicifolia F. Muell.	X		
P. rotundifolia R.Br.			X
Solanaceae			
Solanum linearifolium I.I. Herasimenko		X	X
Goodeniaceae			
Goodenia ovata Sm.	X		X
Asteraceae			
Brachycome rigidula (DC.) G.L. Davis			X
Cassinia aculeata (Labill.) R.Br.			X
C. longifolia R.Br.			X
Cymbonotus sp.	X		X
Helichrysum conditum N.A. Wakefield		X	X
H. obcordatum (DC.) Benth.	X	X	
Olearia iodochroa (F. Muell.) F. Muell. ex Benth.	X	X	
O. phlogopappa (Labill.) DC.	X	X	X
Senecio hispidulus A. Rich.			X
MONOCOTYLEDONEAE			
Poaceae			
Bothriochloa macra (Steud.) S.T. Blake	X		
Chionochloa pallida (R.Br.) S.W.L. Jacobs	X	X	X
Xanthorrhoeaceae			
Xanthorrhoea australis R.Br.			X
Orchidaceae			
Diuris sulphurea R.Br.			X

Distribution and spread of the Alismataceae in the rice-growing region of New South Wales

S. McIntyre and M. R. Newnham

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Abstract

McIntyre[1], S. and Newnham[2], M. R. (CSIRO Centre for Irrigation Research, Griffith, Australia 2680) 1988. Distribution and spread of the Alismataceae in the rice-growing region of New South Wales. Cunninghamia 2(1): 25–38. — The distributions of five species of the Alismataceae are described for the rice-growing region of New South Wales. Two native species occur in the area: *Alisma plantago-aquatica* L. is uncommon, but *Damasonium minus* (R. Br.) Buch. is widespread in wetlands and extremely abundant in rice fields, where it is regarded as a major weed.

Irrigation development has enhanced the introduction and spread of aquatic plants and three members of the Alismataceae have entered the region in the last 20 to 30 years. Within the irrigation areas, the plants have dispersed along irrigation channels and all three have been recorded in rice fields. *Sagittaria montevidensis* Cham. *et* Schlecht. is already widespread in the study area but remains a relatively minor weed of rice. *Alisma lanceolatum* With., although still restricted in distribution, has developed extremely high population levels in rice. *Sagittaria graminea* Michx. is also restricted, but shows more potential as a weed of irrigation channels than of rice fields.

Introduction

The development of irrigation on the Riverine Plain in New South Wales has resulted in some major changes to the region. In the irrigated areas human settlement has greatly intensified and there has been a marked increase in the extent of aquatic habitats. Drainage and supply channels, roadside ditches, irrigated pasture and rice crops are examples of aquatic habitats that have been created in addition to, and have sometimes replaced, the natural wetlands.

Many species of the original wetlands and swamps have successfully colonised these new habitats. In addition, introduced aquatic species have entered the region, assisted by human activity.

The Alismataceae is a family of aquatic plants, represented in the region by five species. Two of these, *Alisma plantago-aquatica* L. and *Damasonium minus* (R. Br.) Buch. are native, and three species are introductions: *Alisma lanceolatum* With., *Sagittaria montevidensis* Cham. *et* Schlecht. and *Sagittaria graminea* Michx. All five species have been recorded in rice fields in the study area.

This paper documents the history of introduction and current distribution of the Alismataceae in the rice-growing areas of New South Wales. The three introduced species are still spreading and have not yet achieved their potential distribution. The information on these three species is presented in detail; it is hoped that this will permit useful documentation of the colonising process.

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Methods

Search strategies

The search areas included the Murrumbidgee, Coleambally and Tullakool Irrigation Areas (I.A.) and the Benerembah, Tabbita and Murray Valley Irrigation Districts (I.D.), a total of over one million hectares. Some additional aquatic habitats were also visited, notably those found in the riverine forests associated with the Murray and Murrumbidgee Rivers. Two alternative search strategies were used to locate the plants, the choice depending on the known abundance of each species..ch

Plants known to be restricted in occurrence. With such an extensive area under study, it was impractical to examine systematically the entire area in detail. Instead, searches radiated from known occurrences and were continued until it was evident that the whole local population had been delineated. Additional searching on a less intensive scale was then conducted over a large area surrounding the known infestations to pick up any satellite populations. This strategy was effective for delineating known occurrences but may have resulted in some isolated localised populations being missed.

Localised populations of restricted species were mapped in detail. These data, together with information from local people, provided evidence for determining possible modes of introduction and spread of the plants.

Plants known to be widely distributed. For widely occurring species, distributions were recorded as points on a map, each represented by a plant collection. Efforts were made to obtain an even spread of points over the entire area in which the species was known to occur.

Plant collections

Collections were made with the intention of fully representing the distribution of each species. Specimens were lodged at the National Herbarium of New South Wales (NSW). All collections were made from January to April 1985, with the exception of several *Sagittaria graminea* specimens which were collected in May 1984.

Where collections were made, local population numbers were estimated on the following scale:

<10	very low
10–100	low
100–1000	medium
1000–10 000	high
>10 000	extremely high

For most species, these values represented numbers of individual plants. An exception was the vegetatively reproducing *Sagittaria graminea*, for which population estimates represented numbers of visually identifiable ramets that look superficially like individual plants but may be joined underground.

Definition of terms

Irrigation channel. This term is used collectively to include supply and drainage channels.

Supply channel. An artificially constructed watercourse for the transport of water from the sources of supply (Murrumbidgee and Murray Rivers) to the farms in the Irrigation Areas and Districts. They are generally filled with water throughout the summer and vary in size depending on the location. Major supply channels are over 20 m wide, while on-farm channels are only a few metres wide.

Drainage channel. These may be natural or artificially constructed watercourses which remove excess water from irrigated land. They are generally shallower than supply channels of equivalent width.

Borrow pit. Flood irrigation is the most common watering method in the region and contour banks are constructed within paddocks to control water movement. When rice is grown, these form the boundary of the bays that remain flooded throughout the season. Borrow pits are narrow ditches that run parallel to the contour banks and are excavated when soil is 'borrowed' to form the bank. They assist in the drainage of water from the paddock and are not generally sown with rice. Consequently, they can provide an open flooded area for the establishment of aquatic plants.

Ditch. This refers to any narrow excavation designed for the collection of water, that is not directly associated with the drainage and supply of irrigation water.

Results and Discussion

Alisma species

Background. *Alisma lanceolatum* is native to Europe, North Africa and West Asia and has since been introduced to Canada, Chile (Häfliger *et al.* 1982) and Australia where it established at Creswick, Victoria some fifty years ago (Aston 1977). The only other collections of *A. lanceolatum* in Australia are from the Mt Lofty Ranges (S.A.), Woori Yallock (Vic.) and Echuca (Vic.). In 1983 it was collected from a rice crop in the Coleambally Irrigation Area, the first record of this species in New South Wales.

Alisma lanceolatum is a principal weed of rice in Southern Europe (Catizone 1981). Barrett and Seaman (1980) also record it for Californian rice fields, where it is rare and not considered to be of importance. Predicting how troublesome *A. lanceolatum* will become in Australian rice fields is guesswork, but the nature and extent of the original infestation in rice suggests that it may be a problem.

Established populations of *A. lanceolatum* were found in the central Coleambally Irrigation Area and the Deniboota Irrigation District, and these are described in detail. The plant was also found in large numbers in drainage channels and roadside ditches in dairying land around Echuca township (Figure 1). These three occurrences are almost certainly disjunct, but it is possible that some isolated populations remain unrecorded in the intervening areas. The method of dispersal and source of material introduced to each of the three sites is unknown, however evidence suggests that the Coleambally and Deniboota infestations originated from separate, long-distance dispersal events.

A second *Alisma* species, *A. plantago-aquatica*, is native to the area but is rare (Figure 1). Although a common rice weed in Brazil, Chile (Gonzalez, Garcia & Perdomo 1983) and in eastern Europe (Podkin, Chanukvadze & Frolova 1983), *A. plantago-aquatica* has been found only as a few plants in two rice crops in New South Wales and is not considered to be a potential threat under current conditions of rice husbandry.

Distribution of *Alisma lanceolatum* in the Coleambally Irrigation Area. The extent of the first population discovered in 1983 was mapped in detail and twelve farms were found to have been colonised by *A. lanceolatum*. Eighteen rice crops were infested to varying degrees and populations were also found in two drainage channels associated with the affected farms. This information is summarised in Figure 2 and Table 1.

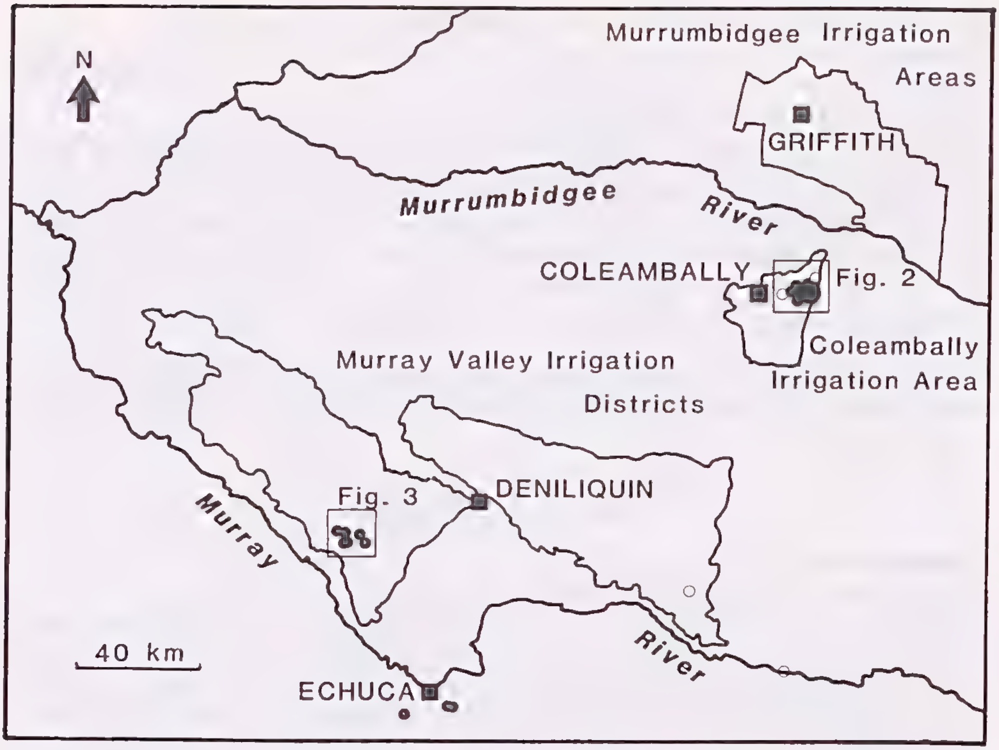
N
Murrumbidgee Irrigation Areas
GRIFFITH
Murrumbidgee River
COLEAMBALLY
Fig. 2
Coleambally Irrigation Area
Murray Valley Irrigation Districts
DENILIQUIN
Fig. 3
Murray River
40 km
ECHUCA

Figure 1. Distribution of *Alisma* spp. in the rice-growing areas of New South Wales, showing locations of collections of *A. lanceolatum* (●) and *A. plantago-aquatica* (○), January to March 1985.

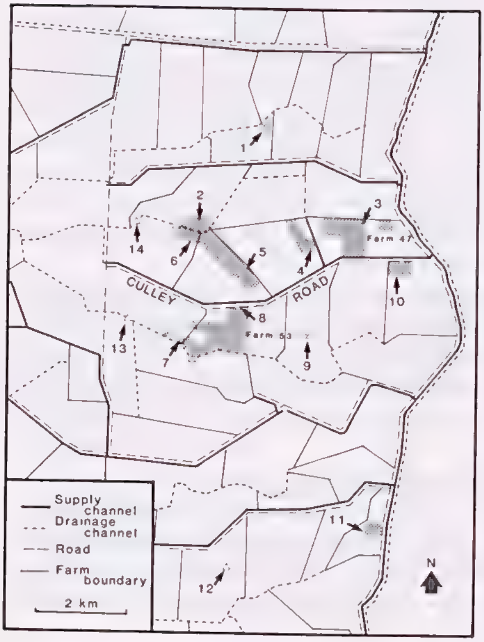

Figure 2. Distribution of *Alisma lanceolatum* in the Coleambally Irrigation Area, showing areas under rice where *A. lanceolatum* occurred (▨), locations of irrigation channel populations (△) and locations of collections (1–14) referred to in Table 1.

Table 1: Details of collections of *Alisma lanceolatum* from the Coleambally Irrigation Area, January to February 1985 (see Figure 2).

Map location number	Collection number	Habitat	Farm number	Population size (number of plants)	Comments
1	MNSM 366	rice crop	30	100–1000	throughout one bay
2	MNSM 358	rice crop	44	10–100	scattered through bay
3	MNSM 350	rice crop	47	1000–10 000	restricted mainly to borrow pits
4	MNSM 355	rice crop	48	100–1000	throughout bays
5	MNSM 356	rice crop	49	100–1000	throughout bays; spread to farm supply
6	MNSM 357	rice crop	50	100–1000	throughout bays
7	MNSM 361	rice crop	52	10–100	in borrow pits of four bays
8	MNSM 339	rice crop	53	>10 000	very severe infestation throughout
8	MNSM 348	rice crop	53	1000–10 000	severe infestation throughout
8	MNSM 338	on-farm supply channel	53	10–100	adjacent paddock infested but fallow
9	MNSM 360	rice crop	54	<10	in borrow pit, two small plants
10	MNSM 340	rice crop	56	100–1000	in crop and adjacent wet, fallow bay
11	MNSM 365	rice crop	96	10–100	throughout crop
12	MNSM 501	on-farm supply channel	99	<10	near uninfested crop
13	MNSM 346	drainage channel	—	<10	—
14	MNSM 352	drainage channel	—	10–100	—

The original infestation is thought to have been on Farm 47 or 53. Both properties were previously owned by the same person and now support considerable populations of *A. lanceolatum*, the largest in the area. There is no evidence of plants growing in supply channels leading to the infested area, suggesting that these farms support the founding population in the Coleambally I.A. The on-farm supply channels that did contain *A. lanceolatum* appear to have been colonised from populations in nearby rice crops. The rash of smaller infestations around these larger populations also appear to have arisen from short-distance dispersal.

Three occurrences of *A. lanceolatum* occur some distance away from the main infestation (Figure 2, sites 1, 11 and 12) and cannot be explained in terms of short-distance dispersal. In all three cases the use of agricultural machinery is strongly implicated in the spread of *A. lanceolatum*. Machinery from heavily infested farms has at some time been used on the land where the three satellite infestations occurred.

In addition to farm machinery, a likely cause of spread of *A. lanceolatum* in the future is the system of drainage channels leaving the affected area. These channels supported a small number of plants (<100) but they were large, well established and prolific producers of seed, which is readily carried downstream. At least one rice crop infestation (Figure 2, site 2) appears to have resulted from dispersal from an infested drainage channel.

***Alisma lanceolatum* in the Deniboota Irrigation District**. The infestation mapped in the Deniboota district was centred approximately 5 km south of Caldwell (Figure 3). Populations were discovered in two ditches, a rice crop and the associated drainage system (Table 2). The area between these locations and the nearest known *A. lanceolatum* at Echuca (40 km southeast) was searched, but no plants were found and it was clear that the Caldwell and Echuca infestations were disjunct.

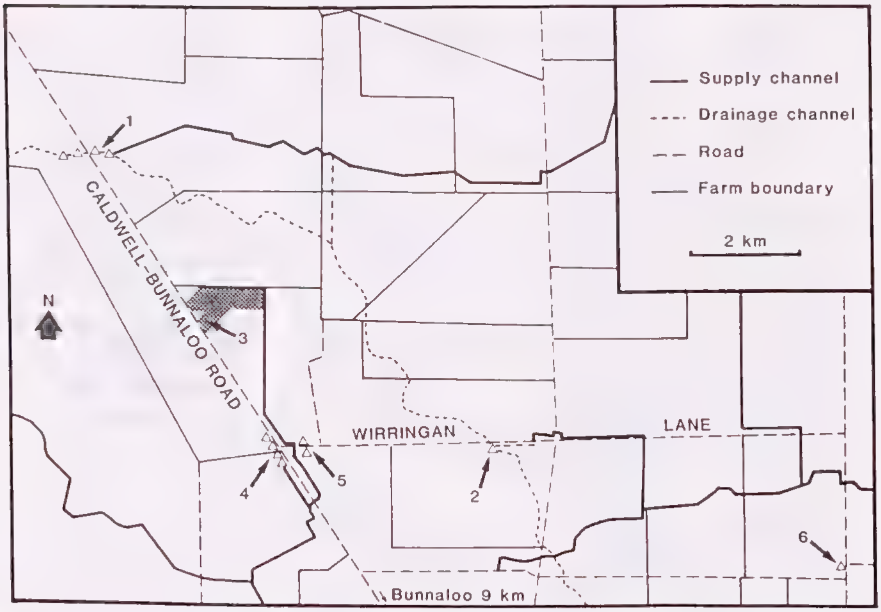

Figure 3. Distribution of *Alisma lanceolatum* in the Deniboota Irrigation District showing extent of populations in rice (▨), locations of populations in ditches and irrigation channels (△) and locations of collections (1–6) referred to in Table 2.

Although the six Caldwell populations are all likely to have arisen from one instance of long-distance dispersal (from Echuca, Coleambally or elsewhere), the founding population could not be identified. The largest infestation occurred in the affected rice crop, but here the large numbers of plants could have been a reflection of the extent of suitable habitat as much as an indicator of infestation age. Rice crops in this area are much more widely separated than in the Coleambally area, where rice fields are in close proximity. The fact that plants were found a considerable distance upstream of the infested crop, in the associated Deniboota Escape Channel, suggests that the rice field does not support the founding population.

The *A. lanceolatum* populations at Caldwell were isolated and scattered in comparison with the Coleambally distribution. The Caldwell infestation did not appear to be spreading on a front; future expansion is dependent on chance events and could occur in any direction. The only predictable direction of spread is downstream from existing populations growing in the Deniboota Escape Channel.

The scattered distribution of *A. lanceolatum* appears to be related to the low intensity of irrigation development in the Deniboota Irrigation District and the associated low density of suitable wet habitats. This situation, which is in contrast to that in the Coleambally area, is probably responsible for the lower number of affected rice crops in the Caldwell area (1 compared with 18 in the Coleambally I.A.). Given present land use in the Deniboota I.D., the rate of spread of *A. lanceolatum* amongst rice crops is likely to be slower than in Coleambally.

Table 2: Location, size and habitat of all populations of *Alisma lanceolatum* mapped in the Deniboota Irrigation District, January to March 1985 (see Figure 3).

Map location number	**Collection number**	**Habitat**	**Population size** (number of plants)	**Comments**
1	MNSM 515	drainage channel	10–100	downstream from infested rice crop
2	MNSM 520	drainage channel	1	upstream from infested rice crop
3	MNSM 517	rice crop	>10 000	growing throughout an aerially sown crop
4	MNSM 518	railway ditch	100–1000	area subject to foot traffic; seasonally wet
5	MNSM 519	roadside ditch	100–1000	growing with *Typha*
6	MNSM 521	intermittent watercourse	10–100	drains into Deniboota Escape (sites 1 & 2)

***Sagittaria* species**

Sagittaria montevidensis

Sagittaria montevidensis is a native of North and South America where it is a weed of rice in California (Barrett & Seaman 1980) and Brazil and Uruguay (Gonzalez *et al.* 1981). Two subspecies have been introduced to Australia, ssp. *calycina* and ssp. *montevidensis*. Both are cultivated as ornamentals and the latter was recorded in Sydney in 1926 (Aston 1977; Sainty & Jacobs 1981). Subspecies *calycina* was first recorded in the Murrumbidgee Irrigation Area in 1962 and has spread rapidly in irrigation channels and rice fields. Although both subspecies are recorded for the Murrumbidgee I.A., it appears that only one, ssp. *calycina*, is widespread and ssp. *montevidensis* was not found in the region. The widespread Californian weed is also referable to ssp. *calycina* and has an annual life cycle. There are also reports of *S. sagittifolia* L. from the Griffith-Leeton district, but they are considered by Aston (1977) to be the result of confusion with *S. montevidensis*.

Since its introduction, *S. montevidensis* has spread southwards and is now also well established in the Coleambally I.A. (Figure 4). It occurs most frequently in drainage channels and rice crops. Recently, an isolated infestation was reported in the Tullakool I.A. This recording was the cause of some concern as it is the first known occurrence of this plant in the Murray Valley region.

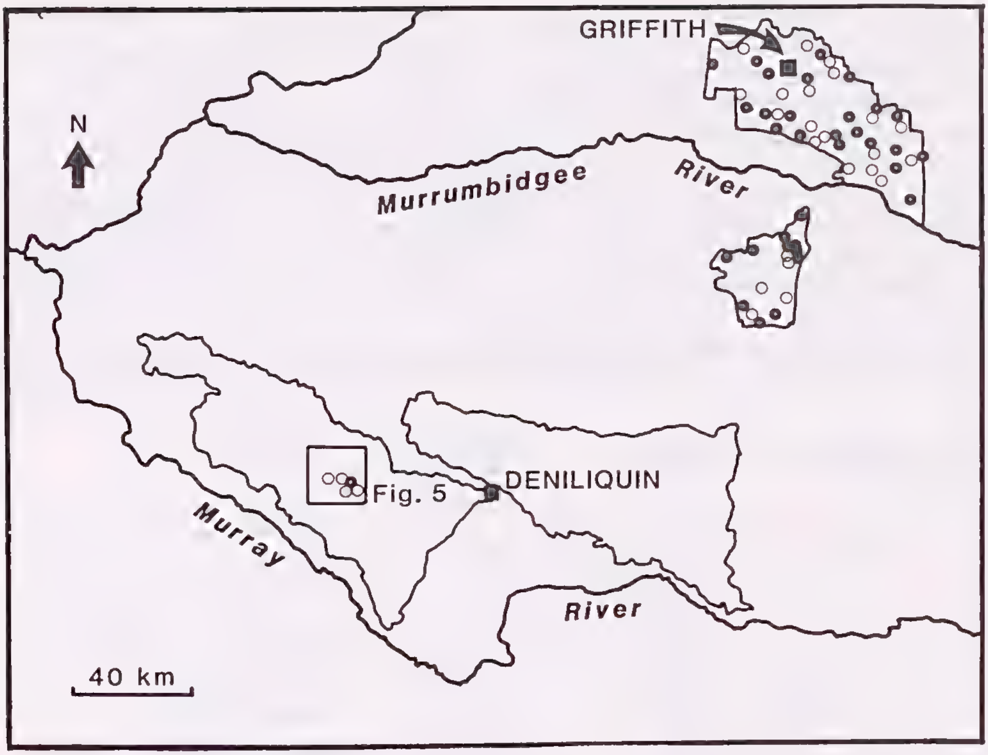

Figure 4. Distribution of *Sagittaria montevidensis* in the rice-growing areas of New South Wales, showing locations of collections from rice crops (●) and irrigation channels (○), 1984–85.

Table 3: Details of collections of *Sagittaria montevidensis* from the Tullakool Irrigation Area, January 1985 (see Figure 5).

Map location number	Collection number	Habitat	Population size (number of plants)	Comments
1	MNSM 418	drainage channel	1000–10 000	drainage from original infestation
2	MNSM 419	rice crop	10–100	3 bays affected along edge adjoining infested channel
3	MNSM 422	drainage channel	<10	flowing west along Burraboi Road
4	MNSM 423	drainage channel	10–100	in Niemur Drain at junction of Burraboi & Tullakool-Moulamein Rds
5	MNSM 424	drainage channel	10–100	tributary of Niemur Drain flowing west, bordering saltworks

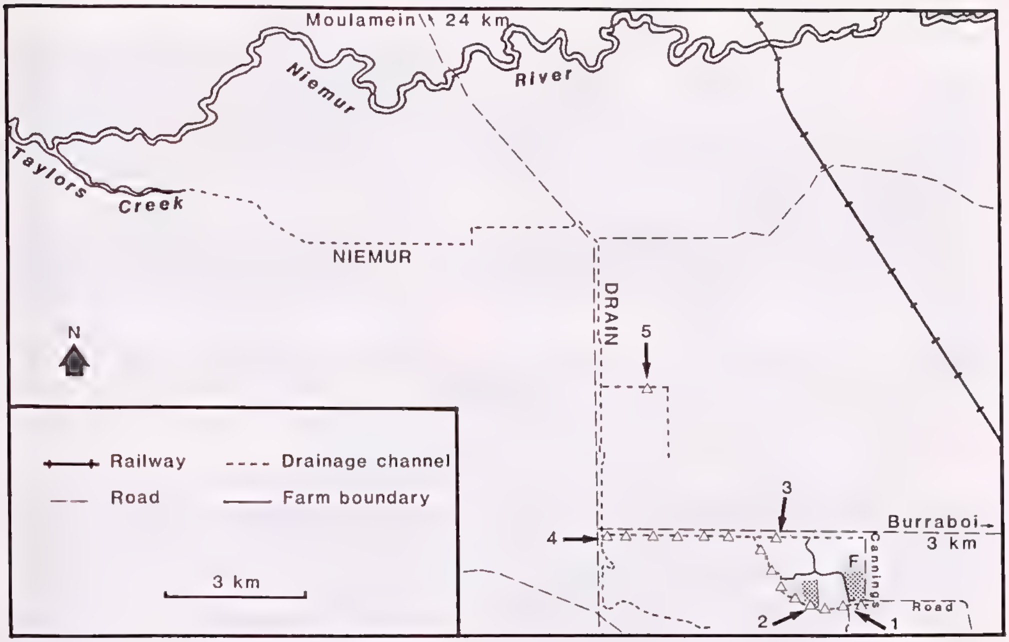

Figure 5. Distribution of *Sagittaria montevidensis* in the Tullakool Irrigation Area, showing extent of irrigation channel populations (△), locations of infested rice crops (▨) and collections (1–5) referred to in Table 3. F = field fallow in 1984–85.

***Sagittaria montevidensis* in the Tullakool Irrigation Area**. An infestation was reported in a rice crop in the Tullakool I.A. in the 1983–84 season. According to the grower, this introduction was the result of sowing contaminated seed. The seed used was from the Murrumbidgee I.A.

The site of the original infestation was fallow at the time of the survey, but *S. montevidensis* had spread into the associated drainage system and this area was mapped (Figure 5, Table 3). The extent of this infestation suggests that the original plants must have been introduced some years ago. *Sagittaria montevidensis* was found to occur sporadically along a 7 km stretch of drainage channel. The Water Resources Commission reported that a further 17.5 km of the Niemur Drain, as far as Taylors Creek, had been colonised but a vigorous spraying program has removed all evidence of these plants.

One rice crop adjacent to the infested channel was found to contain *S. montevidensis*. In this field, three bays were infested and plants were restricted to small clumps at the edge near the channel, suggesting that short-distance dispersal from the channel had occurred.

The introduction of *S. montevidensis* to the Murray Valley was probably inevitable, given the degree of population build-up in the northern irrigation areas. As suggested for *Alisma lanceolatum*, the rate of spread of *S. montevidensis* through the southern irrigation districts is likely to be slower than in irrigation areas, owing to the lower density of aquatic habitats.

Sagittaria graminea

A native of North America, *Sagittaria graminea* was introduced to Australia in the late 1950s and is now naturalised in Queensland, New South Wales and Victoria (Aston 1977). It is regarded as a troublesome weed in north-central Victoria where it obstructs water flow in drainage channels and creeks (Sainty & Jacobs 1981). *Sagittaria graminea* does not appear to be a significant rice weed elsewhere in the world.

Within the rice growing region, *S. graminea* is currently restricted to the Murray Valley where it seems to have entered as two separate introductions, both occurring as disjunct populations in the Berriquin Irrigation District (Figure 6). These are described below.

***Sagittaria graminea* in the Mulwala Canal.** *Sagittaria graminea* appears to have entered New South Wales from north-central Victoria via the Mulwala Canal which flows away from Lake Mulwala on the Murray River (Figure 7, Table 4). This canal is the main supply channel for the Berriquin I.D.

Lake Mulwala itself had been colonised by *S. graminea* and a 30 km stretch of the canal supported sporadic populations. Establishment was restricted to the canal banks where the water was shallow and slow-flowing. Intensive application of herbicides by the Water Resources Commission had limited the extent of the canal populations. Several branch supply channels were infested but plants have since been eradicated. Spot checking of rice crops and channels throughout the district indicated that no populations appeared to have arisen from the canal infestation. The chance of this happening in the future is probably high, but at present the infection pressure is limited as the number of plants in Mulwala Canal is low.

The 'Lindifferon' infestation. Large numbers of *S. graminea* were found on three adjacent holdings in the Berriquin I.D. near Deniliquin (Figure 8, Table 4). This population is over 40 km away from the Mulwala Canal populations.

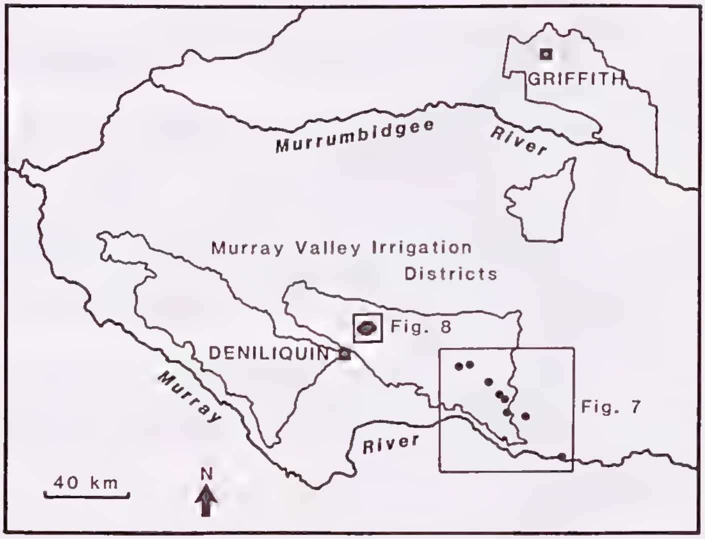

Figure 6. Distribution of *Sagittaria graminea* in the rice-growing areas of New South Wales showing locations of collection sites (●).

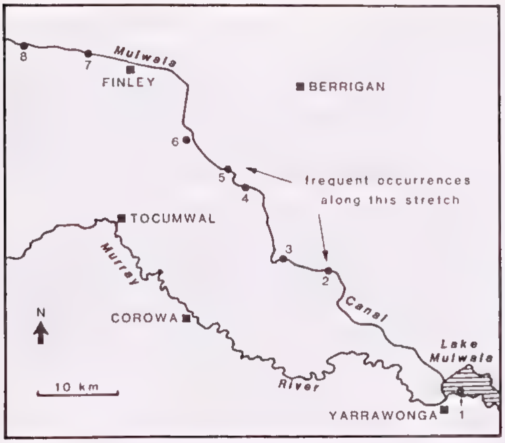

Figure 7. Distribution of *Sagittaria graminea* in the Berriquin Irrigation District, where it has colonized Mulwala Canal from a population in Lake Mulwala. Numbers (1–8) show locations of collections referred to in Table 4.

Table 4: Details of collections of *Sagittaria graminea* from the Berriquin Irrigation District, February to March 1985 (see Figures 7 & 8).

Map location number	Collection number	Habitat	Population size (number of plants)	Comments
1	MNSM 508	Lake Mulwala	10–100	much larger population (>1000 plants) near this collection
2	MNSM 576	Mulwala Canal	<10	broad-leaved plants growing in shade
3	MNSM 506	Mulwala Canal	1000–10 000	restricted to edge of canal which is very deep and wide
4	MNSM 510	Mulwala Canal	100–1000	as for 3
5	MNSM 511	Mulwala Canal	10–100	as for 3
6	MNSM 512	supply channel	10–100	close to point of departure from canal
7	MNSM 513	Mulwala Canal	10–100	as for 3
8	MNSM 514	supply channel	100–1000	50 m downstream from point of departure from canal
9	SM 1002*	supply channel	100–1000	growing throughout channel
10	SM 1003*	rice crop	1000–10 000	population extended to 3 adjoining rice crops
11	MNSM 586	supply channel	100–1000	broad-leaved plants growing in shade
12	MNSM 587	supply channel	100–1000	narrow-leaved plants growing in full sun
13	MNSM 590	supply channel	100–1000	growing throughout channel
14	MNSM 591	supply channel	100–1000	growing throughout channel
15	MNSM 592	rice crop	<10	restricted to borrow pit

* SM 1002 and SM 1003 were assessed for population size in 1985 but collected in May 1984.

On the property 'Lindifferon', a dam near an abandoned farmhouse supports large numbers (1000–10 000 plants) of *S. graminea*. The evidence available, including communications with farmers and the distribution pattern of the weed, indicates that the dam holds the founding population of *S. graminea*. It seems likely that the plant was introduced to the dam as an ornamental many years ago. Two adjacent properties, 'Box Lea' and 'Carmarthan', also support large populations.

On 'Lindifferon', *S. graminea* was limited to the dam, a rice crop and the supply channel between the dam and the crop. The rice crop on 'Box Lea' appeared to be free of the weed, although it grew in the farm supply channels. The third property, 'Carmarthan', was more seriously affected, with *S. graminea* growing in three rice crops and most of the supply channels. In the rice crops *S. graminea* was generally restricted to the borrow pits and areas of low rice plant density.

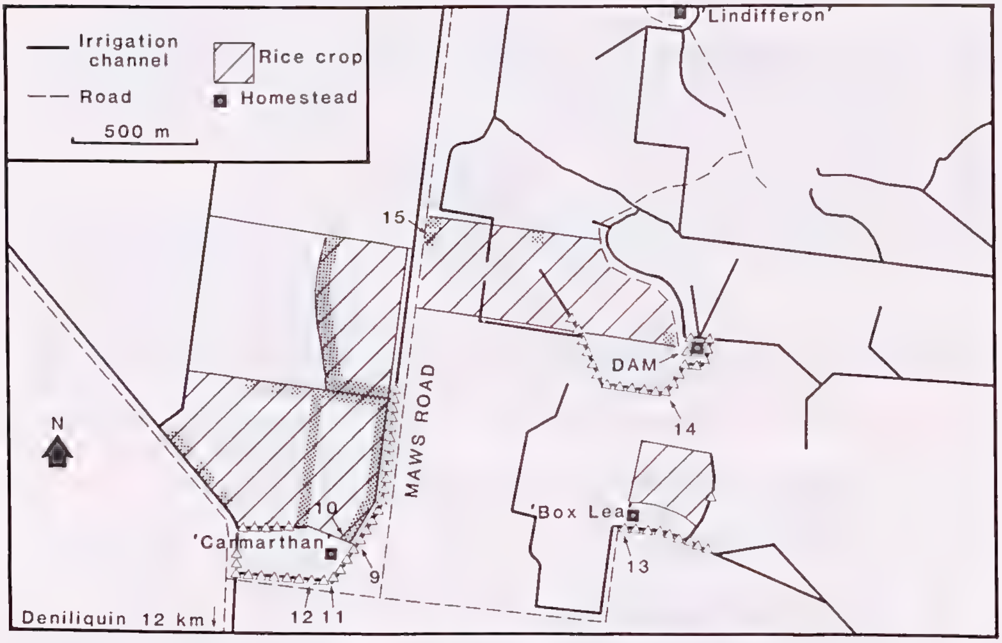

Figure 8. Distribution of *Sagittaria graminea* in the Berriquin Irrigation District, showing locations of populations in rice crops (▒), irrigation channels (△) and locations of collections (9–15) referred to in Table 4.

Damasonium minus

Damasonium minus is an annual plant which is endemic to Australia, where it is the most significant rice weed amongst the Alismataceae. The plant is widespread, but not particularly abundant in natural and seminatural wetlands (S. McIntyre, unpublished data). Plant numbers appear to have built up considerably in rice fields and *D. minus* began to be recognized as an important weed in the 1960s (Swain 1973), some 40 years after rice growing began.

Damasonium minus is widespread in all rice-growing districts; it was recorded at over 70% of sites in a survey of rice fields (McIntyre & Barrett 1985). Because of its abundance, no attempt was made to map *D. minus* and it can be considered ubiquitous in rice crops throughout the study area.

General Discussion

Several features of irrigation development ensure the spread of aquatic species. Plants are readily dispersed by water along the system of channels and spread efficiently over large areas. The movement of farm machinery and vehicles distributes soil, which may contain seed. These two methods appear to be the major dispersal mechanisms within irrigated areas.

Together, these factors make control of undesirable species difficult. Intensive herbicide programs such as those used against *Sagittaria graminea* in the Mulwala Canal and *Sagittaria montevidensis* in the Deniboota district have failed to eradicate these species. Eradication programs can probably only be successful for very small, isolated populations. As no systematic monitoring of weed populations occurs, introductions are often well established by the time they are noticed. Even rigorous monitoring could only be expected to reduce, not prevent, the establishment of new alien aquatic plants in the future.

Members of the Alismataceae have generally benefited from irrigation development. They are most abundant in drainage channels, rice crops and, to a lesser extent, in supply channels, wherever shallow water stands for prolonged periods. They do not often grow in transient wetland habitats such as roadsides and ditches.

The five species showed differing abilities to grow in various habitats. The newly introduced species may not yet have reached their potential range, but there are also differences in ecological characteristics.

Two of the five species appear to be serious competitors in rice crops. *Damasonium minus* is already a widespread, abundant weed, and *Alisma lanceolatum* has developed extremely high population levels within its current range. Interestingly, these species are the only ones to be recorded in ditches or roadsides and may be better adapted to intermittent flooding and high levels of disturbance.

Although widespread, *Sagittaria montevidensis* is not a particularly abundant rice weed in New South Wales, and tends to be restricted to borrow pits on the edge of rice bays. This is in contrast to the situation in California, where it is the most abundant weed of rice (Barrett & Seaman 1980). Such a discrepancy may be related to differences in land use patterns. Unlike *Alisma lanceolatum* and *Damasonium minus*, *S. montevidensis* has poorly developed seed dormancy (B. Cox, unpublished data) that prevents the accumulation of large reserves of viable seed in the soil. In situations where fields are continuously cropped, as is common in California, this characteristic is not a disadvantage because seed populations can be replenished annually. However, these plants would be vulnerable in New South Wales, where crop rotation is usually practised. Under these conditions, annual plants require a bank of dormant seed to survive fallow periods that are unfavourable to plant growth.

The comparative rarity of *Alisma plantago-aquatica* in the rice-growing region can not be explained. Its insignificance as a rice weed is also difficult to account for, especially in view of its importance in rice fields of Brazil, Chile and Europe.

Acknowledgments

This work was conducted from the CSIRO Centre for Irrigation Research, with financial assistance from the Irrigation Research and Extension Committee and the Murray Research and Extension Committee. The authors are also grateful to the following people: M. Bolton and K. Shaw of the Water Resources Commission, for assistance with field localities, Dr S. W. L. Jacobs for help with identifications, Dr P. Y. Ladiges and Dr D. S. Mitchell for helpful comments on the manuscript.

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Catizone, P. (1981). Farmers' weed control technology in rice in southern Europe. In *Weed control in rice* (International Rice Research Institute), pp. 183–191. IRRI, Los Baños, Philippines.

Gonzalez, J., Garcia, E., & Perdomo, M. (1981). Important rice weeds in Latin America. In *Weed control in rice* (International Rice Research Institute), pp. 119–132. IRRI, Los Baños, Philippines.

Häfliger, E., Kühn, U., Hämet-Ahti, L., Cook, C. D. K., Faden, R., & Speta, F. (1982). *Monocot weeds 3*. CIBA-GEIGY, Basle, Switzerland.

McIntyre, S., & Barrett, S. C. H. (1985). A comparison of weed communities of rice in Australia and California. *Proceedings of the Ecological Society of Australia* 14: 237–250.

Podkin, O.V., Chanukvadze, R. G., & Frolova, V. S. (1981). Farmers' weed control technology for water-seeded rice in Eastern Europe. In *Weed control in rice* (International Rice Research Institute), pp. 179–181. IRRI, Los Baños, Philippines.

Sainty, G.R., & Jacobs, S. W. L. (1981). *Waterplants of New South Wales*. New South Wales Water Resources Commission, New South Wales.

Swain, D. J. (1973). Weeds and weed control in rice in New South Wales, Australia. In *Proceedings of the 4th Asian-Pacific Weed Science Society Conference*, pp. 134–139. Rotorua, New Zealand.

Floristic lists of New South Wales (III)

D. A. Keith

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Abstract

Keith, D.A. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1988. Floristic lists of New South Wales (III). Cunninghamia 2(1): 39–73.* — A further two hundred and nineteen floristic lists, mainly from the 1981–85 period, have been collated with notes on the locality, arrangement of species and ecological information. The papers are numbered and ordered according to the botanical subdivisions of New South Wales, authors and dates of compilation.

Introduction

Floristic lists are often the only source of botanical information for a particular area and may serve as a useful starting point for more detailed study. Such lists may be used for general comparisons of the vegetation of different localities, or that of the same locality at different times. The preparation of an increasing number of environmental impact studies and plans of management in recent years has prompted a corresponding interest in floristic lists. This, the third bibliography compiled by the Royal Botanic Gardens, follows the works of Pickard (1972) and Bryant & Benson (1981).

Types of lists included

Similar criteria to those of Pickard (1972) and Bryant & Benson (1981) have been adopted and the journals listed by Bryant & Benson (1981) have been scanned. Most lists are from the 1981–85 period, though a number of older, previously overlooked, lists have been included. The lists range from regional floras to brief lists of predominating species and may or may not include ecological notes on the vegetation, the environment or the abundance of the species. They also vary considerably with regard to the size of the area surveyed and the precision with which this is defined, as well as completeness and the reliability of identifications. Nomenclature may be out of date depending on when the lists were compiled.

The bibliography includes both published and unpublished lists, copies of the latter are held at the Royal Botanic Gardens Library and are available on request from the libarian.

Arrangement of the Bibliography

Unlike the earlier bibliographies, the lists are here arranged according to the botanical subdivision in which they occur. A map of the botanical subdivisions of New South Wales is provided in the end papers. These are explained in full by Anderson (1961). Where a list covers more than one botanical subdivision it is listed under the major subdivision and cross-referenced in other relevant subdivisions. Within the subdivisions the lists are arranged alphabetically by

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* Present Address: National Parks and Wildlife Service, P.O. Box 1967, Hurstville, Australia 2220.

author and then by date. The new arangement is intended to facilitate searching by the geographical area of interest. In this respect it is less cumbersome than the index system used by Pickard (1972) and Bryant & Benson (1981). As a further aid, the name(s) of the relevant 1:250 000 map sheet(s) are given at the end of each reference.

The order of the subdivisions is Lord Howe Island (refs 150–155), North Coast (156–188), Central Coast (189–291), South Coast (292–298), Northern Tablelands (299–302), Central Tablelands (303–319), Southern Tablelands (320–337), North Western Slopes (338–340), Central Western Slopes (341–350), South Western Slopes (351–352), North Western Plains (353–356), South Western Plains, North Far Western Plains (357–360), South Far Western Plains (361–363), New South Wales–General (364–369). The numbering of references follows on from Bryant & Benson (1981).

Each entry in the Bibliography is listed with its author, its date of publication (or compilation if unpublished) and its title. Annotations include the approximate number of species, their arrangement in the list and references to any ecological notes provided on abundance, habitat, soil type, plant communities, etc.

Discussion

The number of floristic lists in the current bibliography when compared with the earlier bibliographies of Pickard (1972) and Bryant & Benson (1981) (Table 1), shows that the annual rate of accumulation of lists is increasing (182 were collected in the 9 years between the first two bibliographies and a further 219 in the five years since the second).

The proportions of lists for the various botanical subdivisions (Table 1) show, apart from an increase in the percentage from the Central Coast since 1972, a decrease in numbers from the Western Slopes and Plains and little change for the

Table 1: Percentage of floristic lists for each of the botanical subdivisions of N.S.W. Data from Pickard (1972), Bryant & Benson (1981) and this paper.

	1972	1981	1985
Lord Howe Island	2	1	3
North Coast	16	16	15
Central Coast	24	35	47
South Coast	1	3	3
Northern Tablelands	8	4	2
Central Tablelands	9	6	8
Southern Tablelands	9	6	8
North Western Slopes	5	4	1
Central Western Slopes	6	5	5
South Western Slopes	3	1	1
North Western Plains	7	4	2
South Western Plains		2	0
North Far Western Plains	3	4	2
South Far Western Plains		5	1
New South Wales — General	5	3	3
TOTAL %	98	99	101
Total number of lists	290	182	219

other subdivisions. While this reflects the booming interest in Sydney's urban bushland, it is a disappointing trend given the very low numbers of lists presently available for other subdivisions, particularly on the Western Slopes and Plains, the Northern Tablelands and the South Coast.

With the increasing availability of computer data banks, the ability to integrate species list data is an important consideration to managers of natural areas. In compiling lists for such purposes, accurate identifications and site localities are essential. Long, unannotated lists covering large, poorly defined areas are less useful. Such lists should be recorded either by sites or by plant communities and should be accompanied, where possible, by descriptions of the relevant plant communities. Data on the relative abundance of the different species may also be worthwhile.

General References

Anderson, R. H. (1961). Flora of New South Wales. Introduction. *Contr. New South Wales Natl. Herb. Flora Series*, Nos 1–18: 1–15.

Bryant, H. J., & Benson, D. H. (1981). Recent floristic lists of New South Wales. *Cunninghamia* 1: 59–77.

Pickard, J. (1972). Annotated bibliography of floristic lists of New South Wales. *Contr. New South Wales Natl. Herb.* 4: 291–317.

Floristic Lists of New South Wales (III)

LORD HOWE ISLAND

150 Pickard, J. (1983). Vegetation of Lord Howe Island. *Cunninghamia* 1: 133–266.

Twenty-five associations in 20 alliances and 14 subformations are mapped at 1:15 840 and described using a novel tabular format. A key to associations is presented. Descriptions include comments on physiography, geology, structure, floristics and disturbance. Vegetation map.

LORD HOWE ISLAND

151 Pickard, J. (1983). Rare or threatened vascular plants of Lord Howe Island. *Biological Conservation* 27: 125–139.

A checklist of 60 species arranged alphabetically by genera under flowering plants and ferns with information on abundance, conservation status and distribution. Text discusses the rarity and threatened status of Lord Howe Island's flora.

LORD HOWE ISLAND

152 Pickard, J. (1984). Exotic plants on Lord Howe Island: distribution in space and time, 1853–1981. *Journal of Biogeography* 11: 181–208.

A checklist of 175 exotic species arranged alphabetically by families and genera within the major plant groups, with information on growth form, first record, continued presence and mode of introduction. Text discusses spatial patterns and temporal trends in weed invasion.

LORD HOWE ISLAND

153 Ramsay, H. P. (1984). The mosses of Lord Howe Island. *Telopea* 2: 549–558.

A checklist of 105 species with distribution information. Families and genera arranged in systematic order, species arranged alphabetically.

LORD HOWE ISLAND

154 Rodd, A. N., & Pickard, J. (1983). Census of vascular flora of Lord Howe Island. *Cunninghamia* 1: 269–280.

List of 379 species, arranged within the major plant groups alphabetically by families and genera with full synonymy and an index to common names. Separate lists are given for native and naturalized species and 33 previously recorded species have been deleted. Endemic species and genera are marked.

LORD HOWE ISLAND

155 Hutton, I. (1984). Vegetation survey report for the site of the proposed wind powered generator on Lord Howe Island. Energy Authority of New South Wales. (Unpub.).

Forty species are listed alphabetically by genus in Appendix 2. Naturalized, non-native and endemic species are annotated. Growth form and some common names are given.

LORD HOWE ISLAND

NORTH COAST

156 Anon. (undated). Kendall Management Area — plant species list. Forestry Commission of New South Wales. (Unpub.).

Checklist of 417 species listed alphabetically by families and genera with information on distribution ranges, habits, habitats, conservation status and localities.

HASTINGS

157 Adam, P. (1985). Species recorded from the Forbes River Crossing and Racecourse areas, Werrikimbee National Park. (Unpub.).

A checklist of 90 species arranged alphabetically by families with authorities and locality records.

HASTINGS

158 Atkinson, G., Hutchings, P., Johnson, M., Johnson, W. D., & Melville, M. D. (1981). An ecological investigation of the Myall Lakes Region. *Aust. J. Ecol.* 6: 299–327.

Aquatic and terrestrial vegetation. Forty-five species listed from 15 sites. Species also mentioned in text.

NEWCASTLE

159 Bartrim, G. (1980). Plant species occurring on the proposed Pipe Clay Creek Nature Reserve excluding Schnapper Island. In Flora & fauna survey of the proposed Pipe Clay Creek Nature Reserve excluding Schnapper Island. (Unpub.).

Checklist of 117 species, the families and genera arranged alphabetically within the major plant groups with common names, habitat, habit and abundance information. Location map. See ref. 176 (Floyd, 1980).

HASTINGS

160 Blakely, W. E., & Shiress, A. W. C. (1922). Flora of Ramornie. (Unpub.).

Checklist of 440 species. Compiled by J. Pickard (1974) from an annotated copy of Maiden & Betche (1916) *Census of New South Wales plants.*

GRAFTON

161 Coveny, R. (1981). Floristic list for Hat Head National Park, east of Kempsey. (Unpub.).

A checklist of 201 species listed in alphabetical order by genus.

HASTINGS

162 de Castro Lopo, L. (1981). *Plant communities of the Booti-Booti State Recreation Area.* Research Papers in Geography No. 25. (University of Newcastle: Newcastle).

Five hundred and ninety-six species are recorded in families under major plant group headings; 24 vegetation types are described for six landform units. Vegetation map.

NEWCASTLE

163 Floyd, A. (undated). Sea Acres Wildlife Refuge. (Unpub.).

Brief descriptions of vegetation communities on exposed seaward slopes including physiography, dominant species, species diversity and number of tree species. (Near Port Macquarie). See ref. 164 (Floyd, 1961, 1976 & 1979).

HASTINGS

164 Floyd, A. (1961, 1976 & 1979). Vegetation description and plant species listing for Sea Acres Wildlife Refuge, Port Macquarie. Appendix A of the Classification Card for the Port Macquarie Coastal Conservation Area, National Trust of Australia (NSW). (Unpub.).

Checklist of 171 species arranged by family and genus within growth form types. Common names are given and introduced species marked, accompanied by brief description of habitat types. See ref. 163 (Floyd, undated).

HASTINGS

165 Floyd, A. (1969a). Forests of the Tweed Valley — Mt Warning. University of New England. (Unpub.).

A checklist of 104 species, the genera listed alphabetically within systematically arranged families for each community-type. Includes common names and abundance information. Additional species recorded by Floyd & Coveny (1977) (referenced in Bryant & Benson, 1981).

TWEED HEADS

166 Floyd, A. (1969b). Forests of the Tweed Valley — history and origin of the Tweed. University of New England. (Unpub.).

An account of the geological events of the last 135 million years (Cretaceous to recent) and their influence on the vegetation of the region.

TWEED HEADS

167 Floyd, A. (1969c). Forests of the Tweed Valley — plants of Stotts Island, Tweed River. University of New England. (Unpub.).

A checklist of 79 species, the genera arranged alphabetically in systematically arranged families. Includes common names and abundance information within each community type. Vegetation map.

TWEED HEADS

168 Floyd, A. (1969d). Species list for Whian Whian State Forest. University of New England. (Unpub.).

A checklist of 142 species, the genera arranged alphabetically within systematically arranged families, with common names and abundance information.

TWEED HEADS

169 Floyd, A. (1969e). Whian Whian State Forest, Big Scrub. University of New England. (Unpub.).

A checklist of 111 species, the genera and families arranged systematically. Geological information provided.

TWEED HEADS

170 Floyd, A. (1969f). At the foot of Minyon Falls, Whian Whian State Forest. University of New England. (Unpub.).
A checklist of 46 species, the genera arranged alphabetically within systematically arranged families. Includes abundance estimates.
TWEED HEADS

171 Floyd, A. (1969g). Species list for Acacia Plateau State Forest. University of New England. (Unpub.).
A checklist of 76 species, the genera arranged alphabetically within systematically arranged families. Common names and abundance information provided.
WARWICK

172 Floyd, A. (1969h). Species list for Beaury State Forest. University of New England. (Unpub.).
A checklist of 84 species, the genera arranged alphabetically within systematically arranged families. Common names and abundance information provided.
WARWICK

173 Floyd, A. (1969i). Tooloom State Forest — Scrub. University of New England. (Unpub.).
A checklist of 59 species, the genera and families arranged systematically.
WARWICK

174 Floyd, A. (1969j). Species list for Wiangarie State Forest. University of New England. (Unpub.).
A checklist of 142 species, the genera in alphabetical order within systematically arranged families in the major plant groups.
WARWICK, TWEED HEADS

175 Floyd, A. (1976). Species list — Allambie Island, Taree. (Unpub.).
A checklist of 69 species arranged according to habit in each community type; the genera in alphabetical order within systematically arranged families. Includes common names, abundance information and comments on the condition of the forest. (Note: Allambie Island is now known as Coocumbac Island.)
HASTINGS

176 Floyd, A. (1980). Floral species list of Schnapper Island. In Flora & fauna survey of the proposed Pipe Clay Creek Nature Reserve. (Unpub.). Compiled by G. Bartrim.
Checklist of species arranged within life form and habitat types. The genera are arranged in alphabetical order within systematically arranged families. Common names and abundance information are provided and exotic species marked. See ref. 159 (Bartrim, 1980). Location map.
HASTINGS

177 Floyd, A., & Coveny, R. (1977). Brunswick Heads — species list. Royal Botanic Gardens, Sydney. (Unpub.).
A list of 84 species compiled by Floyd and arranged alpabetically by genus in systematically arranged families with common names and abundance information. An additional 91 species are recorded by Coveny alphabetically by genus.
TWEED HEADS

178 Fox, M. (1983). *A vegetation survey of the Washpool area, northern New South*

Wales. (Department of Environment & Planning: Sydney).

Species listed alphabetically by family and genus in Appendix II. Separate list of rare species with comments in Appendix III. Tree species listed with common names in Appendix IV. The accompanying report describes and classifies vegetation types of the area and evaluates the impact of logging.

GRAFTON

179 Gregson, J. (1902). A list of foliaceous lichens collected from the Gloucester district. (Unpub.).

Ten species listed with authorities determined by E. Cheel, 1902. Vouchers kept at National Herbarium of N.S.W.

NEWCASTLE, HASTINGS

180 Harden, G., Fox, M., & Stockard, J. (1984). Wingham Brush species list. (Unpub.). Based on ref. 175 (Floyd, 1976).

A checklist of 156 species arranged alphabetically by families and genera within the major plant groups. Common names, growth forms and abundance information given and exotic species marked.

HASTINGS

181 National Parks & Wildlife Service (1981). *Mt Warning National Park Draft Plan of Management*. (N.P.W.S.: Sydney).

Five lists for different altitudinal habitats. Families arranged systematically within growth form categories. Common names, abundance estimates and some localities are provided. Exotic species annotated.
Subtropical rainforest on low slopes (630m), about 200 spp. Warm tropical rainforest on mid-upper slopes (630–1000m), about 110 spp. Base of rock face (700m), about 70 spp. Rock face (930m), about 35 spp. Top of cliff (1000–1105m), about 25 spp.

TWEED HEADS

182 National Trust of Australia (NSW) (1981). Wingham Brush — Plan of Management. (Unpub.).

About 120 species listed in systematically arranged families within growth form categories. Abundance estimates and common names given.

HASTINGS

183 Outhred, R. K., & Buckney, R. T. (1983). The vegetation of Kooragang Island, New South Wales. *Wetlands* 3: 58–70.

A checklist of 102 species listed alphabetically with quantitative habitat and size class data on some of the dominant trees. Eleven extra species not recorded in sample sites are listed separately. Descriptions of habitat types are included in text.

A more detailed account of the same vegetation survey is given in J. Moss (ed.) (1983), *Investigation of the natural areas of Kooragang Island*. (Department of Environment & Planning: Sydney).

NEWCASTLE

184 Pressey, R. L. (1981). A survey of wetlands on the lower Hunter flood plain. National Parks & Wildlife Service. (Unpub.).

Wetlands are mapped, described and evaluated. The extent of 25 wetland habitats is estimated at 168 sites. Most are characterized by single species; the species composition of the more complex habitats is described in the text. Location map.

NEWCASTLE

185 Rodd, A. N. (1981). List of species collected from rainforest at Mungo Brush.

(Unpub.).

A checklist of 42 species arranged alphabetically by families and genera in the major plant groups. Specimens lodged at the National Herbarium of N.S.W. are annotated with collecting numbers.

NEWCASTLE

186 Waterhouse, D. R. (1976). *Four conservation areas for Newcastle — proposals of the National Parks Association of New South Wales* (National Parks Association of New South Wales: Sydney).

Common species mentioned in text for Sugarloaf Range, Bow Wow Creek and Pipe Clay Creek. Five plant communities are briefly described with a list of c. 70 species for the Newcastle Bight dunes arranged alphabetically by genus.

NEWCASTLE

187 White, E. G., Griffith, S. J., & Quint, G. (1984). List of native plants at Goanna Headland. Classification Card for Goanna Headland Coastal Conservation Area. National Trust of Australia (NSW). (Unpub.).

A checklist of 245 species arranged alphabetically by families and genera within the major plant groups. Common names given.

MACLEAN

188 Williams, J. B. (1982). *Plants of coastal heath, scrub and swamp-heath in northern New South Wales.* (University of New England: Armidale).

A checklist of 360 species arranged alphabetically by families and genera within the major plant groups. Includes information on vegetation type and soil type for each species. Text discusses soil–vegetation relationships. List covers coastal areas north of Macleay River.

COFFS HARBOUR, DORRIGO, MACLEAN, TWEED HEADS

For additional lists also relevant to the North Coast see ref. 189 (Adam, 1981), ref. 194 (Archer, 1980), and ref. 282 (Stevens, 1979).

CENTRAL COAST

189 Adam, P. (1981). Saltmarsh plants of New South Wales. *Wetlands* 1: 11–19.

Includes descriptions, illustrations and a key to 42 common saltmarsh plants of New South Wales.

TWEED HEADS, MACLEAN, COFFS HARBOUR, HASTINGS, NEWCASTLE, SYDNEY, WOLLONGONG, ULLADULLA, BEGA, MALLACOOTA

190 Adam, P., & King, R. J. (1981). *The Botany of Botany Bay.* Field Excursion Handbook No. 44. (XIII International Botanical Congress: Sydney).

A brief description of the mangrove, saltmash, forest and coastal heath communities, with checklists for the saltmarshes and mangroves (9 species) and coastal heaths (163 species); the families and genera arranged alphabetically within the major plant groups.

SYDNEY, WOLLONGONG

191 Adam, P., & Murray, A. (1979). Long Neck Lagoon — species list. (Unpub.).

Checklist of 74 species, the genera arranged alphabetically within systematically arranged families.

SYDNEY

192 Akkersdyk, P. (1984). Royal National Park species list. (Unpub.).

A checklist of about 1080 species arranged alphabetically by families and genera.

WOLLONGONG

193 ANZAAS (1952). Notes on Excursion No. 23. Ku-ring-gai Chase–Church

Point–Long Reef. (Unpub.).

Includes checklists for laterite forest, Sorlie (67 species); sandstone scrub, McCarrs Creek (164 species); brush forest, McCarrs Creek (62 species); mangroves and saltmarsh, Bayview (8 species); and brackish lagoon sedge meadow, Dee Why (47 species); arranged in systematic order. Text describes the route of the excursion and the climate, geology, physiography, soils and vegetation of the area.

SYDNEY

194 Archer, A. W. (1980). List of lichens collected in New South Wales 1977–1980. (Unpub.).

A checklist of lichen species found in eastern N.S.W., the genera arranged alphabetically within each locality. Includes more detailed location and habitat information.

SYDNEY, WOLLONGONG, NEWCASTLE, DORRIGO

195 Benson, D. H. (1978). Vegetation Survey: Mt White–Calga/Kariong. In *Freeway No. 3 — Sydney–Newcastle Freeway. Section — Mount White to Ourimbah. Environmental Impact Statement.* Additional Environmental Information Volume. (New South Wales Department of Main Roads: Sydney).

Description of 11 vegetation communities with information on the main species, habitat, distribution and impacts of proposed freeway. Additional comments are provided on species richness and rare species. Location and vegetation maps. For the corridor between Kariong and Ourimbah see ref. 209 (Benson & Fallding, 1979).

SYDNEY

196 Benson, D. H. (1979). Report on native vegetation — Edna May Hunt Reserve, Hillside Crescent, Epping. (Unpub.).

Includes a brief description of the vegetation communities and a checklist of 65 species, arranged alphabetically by genus, annotated with families, common names, and growth form information. Introduced species marked.

SYDNEY

197 Benson, D. H. (1981a). Flora of the Minnamurra Falls Reserve, New South Wales. Compilation of the lists of L. A. S. Johnson (1953), R. Coveny (1979) and H. Judd. (Unpub.).

Lists arranged in major plant groups, under growth form headings, coded for abundance and habitat; about 270 species.

WOLLONGONG

198 Benson, D. H. (1981b). Vegetation of Upper Mangrove Creek, Wyong, New South Wales. *Cunninghamia* 1: 7–22.

A checklist of 196 species arranged alphabetically by families and genera. Occurrence in each of four communities is recorded. Text describes four vegetation communities.

SYDNEY

199 Benson, D. H. (1981c). Vegetation of the Agnes Banks sand deposit, Richmond, New South Wales. *Cunninghamia* 1: 35–58.

A checklist of 136 species listed alphabetically by families and genera within the major plant groups. Table shows growth form, frequency of occurrence, and mode of regeneration after fire. Text describes five vegetation communities and discusses the results of ordination and cluster analyses.

SYDNEY

200 Benson, D. H. (1981d). Vegetation of Lion Island, Broken Bay, New South Wales. *Cunninghamia* 1: 121–124.

A checklist of 90 species listed alphabetically by families and genera within the major plant groups. Text includes a brief description of the vegetation.
SYDNEY

201 Benson, D. H. (1983). Plant species originally native in Concord Municipality. In S. Coupe (ed.), *Concord: a centenary history* (Concord Municipal Council: Concord).
Checklist of 84 species listed alphabetically by family with common names, growth form and geological information. A brief description of Concord's original vegetation is presented in Chapter 1.
SYDNEY

202 Benson, D. H. (1984a). List of plants growing on Bar Island, Hawkesbury River. (Unpub.).
A checklist of 90 species arranged alphabetically by families and genera.
SYDNEY

203 Benson, D. H. (1984b). Floristic lists for Sydney Region Vegetation Series 1:100 000 map sheets. (Unpub.).
Floristic lists of varying length for native species for Gosford and Lake Macquarie, Wallerawang and Burragorang 1:100 000 map sheets with major plant communities indicated. Lists are progressively updated and expanded.
SYDNEY, WOLLONGONG

204 Benson, D. H. (1985a). List of native plants growing on Goat Island, Sydney Harbour. (Unpub.).
A checklist of 44 species arranged alphabetically by families and genera within the major plant groups.
SYDNEY

205 Benson, D. H. (1985b). Species list for upper Magdala Creek, Springwood. (Unpub.).
A checklist of 60 species arranged alphabetically by families within the major plant groups. Exotics indicated.
SYDNEY

206 Benson, D. H. (1985c). Aspects of the ecology of a rare tree species *Eucalyptus benthamii*, at Bents Basin, Wallacia. *Cunninghamia* 1: 371-383.
A checklist of 86 species associated with *E. benthamii* arranged alphabetically by families and genera in the major plant groups. Exotic species marked as garden escapes or agricultural weeds.
SYDNEY

207 Benson, D. H., Coveny, R., & Hind, P. (1983–84). Floristic list for Castlereagh State Forest. (Unpub.).
Checklist of 258 species arranged alphabetically by families and genera within the major plant groups. Includes six fungi species. Exotic species indicated.
SYDNEY

208 Benson, D.H., Coveny, R., & Keith, D.A. (1985). Native species recorded in Mill Stream section of Botany Swamps. (Unpub.).
A checklist of 51 species arranged alphabetically by families and genera in the major plant groups.
SYDNEY

209 Benson, D. H., & Fallding, H. B. (1979). Vegetation Survey: Kariong–

Ourimbah. In *Freeway No. 3 — Sydney-Newcastle Freeway. Section — Mt White to Ourimbah. Enironmental Impact Statement.* Additional Environmental Information Volume. (New South Wales Department of Main Roads: Sydney).

A checklist of 310 species listed alphabetically by genus within growth form categories. Family names and the occurrence of each species in respective vegetation communities are indicated and exotic species marked. Accompanying text includes impacts of the proposal. Vegetation map. For the corridor between Mt White and Kariong see ref. 195 (Benson, 1978).
SYDNEY

210 Benson, D. H., & Keith, D. A. (1984a). Floristic list for Dalrymple Hay Nature Reserve. (Unpub.).

A checklist of 92 species arranged alphabetically by family and genus within the major plant groups.
SYDNEY

211 Benson, D. H., & Keith, D. A. (1984b). Floristic list for Fagan Park, Galston. (Unpub.).

A list of 85 species arranged alphabetically by families and genera.
SYDNEY

212 Benson, D. H., & Keith, D. A. (1984c). Floristic list for Macquarie Hospital Bushland, Twin Road and Cressy Road, East Ryde. (Unpub.).

A checklist of 123 species arranged alphabetically by families and genera within the major plant groups. Abundance and occurrence on sandstone or shale is indicated for each species.
SYDNEY

213 Benson, D. H., & Keith, D. A. (1985a). Species list for the Leo Smith Reserve, Ramsgate. (Unpub.).

A checklist of 63 species arranged alphabetically by families and genera in the major plant groups with abundance information and exotic species marked.
SYDNEY

214 Benson, D.H., & Keith, D.A. (1985b). List of native species recorded on Metropolitan Water, Sewerage & Drainage Board proposed water pollution control plant site, Rouse Hill. (Unpub.).

A checklist of 99 species arranged alphabetically by families and genera with abundance estimates for the occurrence of each species in sandstone woodland or along a creek.
SYDNEY

215 Benson, D.H., Keith, D.A., & Dalby, J. (1985). Native flora of Silverwater Armament Depot. (Unpub.).

Separate checklists for forest on shale (103 spp.) and wetlands (19 spp.), arranged alphabetically by families and genera within the major plant groups.
SYDNEY

216 Benson, J. S. & Fallding, H.B. (1981). Vegetation survey of Brisbane Water National Park and environs. *Cunninghamia* 1: 79–113.

A checklist of 657 species listed alphabetically by families and genera in the major plant groups with annotations showing the occurrence of each species in relevant vegetation communities. Descriptions of the study area, vegetation communities, rare and restricted species and comments on their conservation status are given in the text. Vegetation map at 1:50 000 scale.
SYDNEY

217 Betteridge, C. (1981). *The Plants of Gore Hill Cemetery.* Heritage Council Newsheet 6. (Department of Environment and Planning: Sydney).

A checklist of 123 species listed alphabetically by genus within growth form categories. A listing of plants and their symbolism is also given. Text contains an appraisal of the landscape and vegetation of the cemetery.

SYDNEY

218 Blombery, A. M. (1973). Stony Range Flora Reserve. *Austral. Pl.* 7: 94–156.

Includes a checklist of 548 species cultivated in the reserve, arranged alphabetically by families and genera. Brief description of each species; those native to the reserve or area are indicated. Text describes vegetation, topography, history and horticultural practices in the reserve.

SYDNEY

219 Buchanan, R. A. (1979). *Mowbray Park: description and management.* (Mowbray Park Preservation Society: Sydney).

Description of vegetation and topography for bushland along Lane Cove River with management recommendations. List of over 200 species under major plant groupings, arranged alphabetically within families. Weeds and endangered species indicated.

SYDNEY

220 Buchanan, R. A. (1980). The Lambert Peninsula, Ku-ring-gai Chase National Park. Physiography and the distribution of podzols, shrublands and swamps, with details of the swamp vegetation and sediments. *Proc. Linn. Soc. N.S.W.* 104: 73–94.

List of 44 species found in four swamp types and in moist shrubland. Text describes vegetation and geomorphology of the study area.

SYDNEY

221 Buchanan, R. A. (1982). Ahimsa — plan of management. (Unpub.).

A checklist of 149 species listed alphabetically by families and genera, with abundance estimates for each species on different sections of the National Trust property at Cheltenham. Weed species and ornamental introductions indicated. Text contains a description of the vegetation and discusses management issues.

SYDNEY

222 Buchanan, R. A., & Humphreys, G. S. (1980). The vegetation on two podzols on the Hornsby Plateau, Sydney. *Proc. Linn. Soc. N.S.W.* 104: 49–71.

Species list in appendix. Sixty-four species arranged alphabetically within systematically arranged families in the major plant groups. Text discusses vegetation patterns on the podzols.

SYDNEY

223 Clark, S. S. (1984). Report on areas of closed (rainforest) vegetation. Proposed waste emplacement area, South Bulli Colliery, Bellambi Coal Company. (Unpub.). Cited as an appendix in the Environment Impact Statement for the above proposal.

A checklist of 74 species arranged alphabetically by genus within systematically arranged families under growth form headings. Presence/absence recorded for four different areas. Text describes vegetation and evaluates its condition.

WOLLONGONG

224 Clemens, J. (1984). Species list for North Head Peninsula. (Unpub.).

A checklist of 232 species, the families and genera arranged alphabetically within the major plant groups. Endangered, protected and

introduced species indicated.
SYDNEY

225 Clemens, J., & Franklin, M. H. (1980). A description of coastal heath at North Head, Sydney Harbour National Park: Impact of recreation and other disturbance since 1951. *Aust. J. Bot.* 28: 463–478.
Two types of heath identified, with species lists of 13 and 26 respectively. Mode of regeneration after fire given for each species.
SYDNEY

226 Collier, B. (1983). Plant list of Munmorah State Recreation Area to 25/4/83 with additions to 9/5/83. (Unpub.).
A checklist of 262 species arranged alphabetically by genus with widespread, common and locally abundant species marked. Tentative identifications are indicated for some taxa.
SYDNEY

227 Coveny, R. G. (1982). Checklist for Maddens Plains—about 1km north of Sublime Point. (Unpub.).
A checklist of 190 species listed alphabetically by genera, exotics indicated, includes some fungi.
WOLLONGONG

228 Coveny, R. G. (1983). Wheeny Creek, Wollemi National Park. (Unpub.).
Checklist of 196 species arranged alphabetically by genus with exotic species marked.
SYDNEY

229 Davenport Campbell & Partners Pty Ltd (1984). Singles Ridge Area Local Environmental Study. (Unpub.).
Checklists for Purvines Road (57 native species), Yellow Rock Trail (26 native species), downstream of North Richmond Sewerage Works (24 native species) and weeds noted on Fraser and Fitzgeralds Creeks (13 species) listed under habitat types and growth form categories. Text contains a brief description of the vegetation and an assessment of weed invasion. Singles Ridge is near Springwood.
SYDNEY

230 Elouera Bushland Natural Park Trust (1983). *A Guide to Elouera Bushland Natural Park*. (Elouera Bushland Natural Park Trust: Hornsby).
A checklist of 430 species is presented in Appendix 2, arranged alphabetically by genera with exotic species indicated.
SYDNEY

231 Farrant, P. A., & King, R. J. (1982). Subtidal seaweed communities of the Sydney region. *Wetlands* 2: 51–60.
A checklist of 59 algal species arranged in divisions, orders, families and genera with locality information for five sites in Sydney Harbour. Text describes algal associations at each site and discusses distributional patterns.
SYDNEY

232 Fuller, L. (1980). *Wollongong's native trees*. (L. Fuller & R. Badans: Kiama).
Over 120 species described alphabetically by genus with photographs and distribution maps. Additional notes on habitats and plant communities. A general overview of the history and geography of Wollongong is also presented.
WOLLONGONG

233 Fuller, L., & Mills, K. (1985). *Native Trees of central Illawarra* (Weston & Co. Publishers Pty Ltd: Kiama).

Drawings, brief descriptions and distribution maps of 140 tree species arranged alphabetically by genus. Common names and families given. Includes photographs of a further 24 shrub species sometimes encountered as trees. Appendix lists trees typically found in 14 different habitats. Text describes landforms, geology and climate of area and discusses patterns of distribution.

WOLLONGONG

234 Haegi, L., & Benson, D. H. (1981). *Sclerophylls, sandstone and scenic splendor: a wilderness walk in Wollemi National Park, N.S.W.* Field Excursion Handbook No. 18/4 and 18/5. (XIII International Botanical Congress: Sydney).

Checklists of main species are given for Culoul Range turnoff (28 species); basalt vegetation — Six Brothers to Hollow Rock (54 species); Boorai Ridge (58 species); Colo Gorge and Dooli Creek (90 species); Dooli Creek Waterfall (17 species); Boorai Creek (76 species); Mopoke Flat Campsite (12 species); sandstone slopes near Mopoke Flate Campsite (10 species); and Mopoke Flat to Hollow Rock (46 species); all arranged alphabetically by genus within growth-form categories. Common names and families given.

SYDNEY

235 Hickey, E., & Quint, G. (1982). Royal Australian Navy Land — Silverwater, Plant Listing. (Unpub.).

A checklist of 46 species listed alphabetically by families and genera within the major plant groups. Common names given and exotic species marked.

SYDNEY

236 Holland, D. (1980). Mount Trefle: A general and botanical study within Sydney Harbour National Park. Student report for Ryde School of Horticulture. (Unpub.).

Text describes the history, geology, soils, climate and vegetation of the area with specific comments on plant communities, fire and weed control. Checklist of 115 species arranged alphabetically by families and genera, exotic species marked. A separate list shows community composition.

SYDNEY

237 Hutchings, P. A., Pickard, J., Recher, H. F., & Weate, P. B. (1977). A survey of mangroves at Brooklyn, Hawkesbury River. *Operculum* 5: 105–112.

A brief account of the flora of the mangrove communities and their associated fauna with an evaluation of the effects of reclamation. Includes qualitative transect data for vegetation and quantitative transect data for fauna.

SYDNEY

238 Jarvie, L., Pople, L., Robertson, C., & Sajn, D. (1985). List of vascular plant species for Davidson State Recreation Area. (Unpub.).

A checklist of 454 species arranged alphabetically by families and genera within the major plant groups. Sources of other records given. Exotic and rare and endangered species marked.

SYDNEY

239 Keith, D. A. (1984). Plant species occurring in a park on the corner of Epping Road and Delhi Road, North Ryde. (Unpub.).

A checklist of 109 species arranged alphabetically by families and genera

within the major plant groups. Each species is categorized as indigenous, cultivated or exotic and abundance estimates are given. Comments are made regarding the value of this area with respect to remnant vegetation on Sydney's Wianamatta Shale and the effect of cultivating non-indigenous Australian native plants in such areas.
SYDNEY

240 Keith, D. A. (1985). Species list for Eric Mobbs Reserve, Carlingford. (Unpub.).
A checklist of 95 species arranged alphabetically by families and genera within the major plant groups. Exotic species marked.
SYDNEY

241 Keith, D.A., & Fallding, H.B. (1985). Prospect Creek, Smithfield, species list. (Unpub.).
A checklist of 76 species arranged alphabetically by families and genera within the major plant groups. Exotic species marked.
SYDNEY

242 Kinhill Stearns (1985). Native plant species occurring on the proposed airport site at Badgerys Creek. In *Draft Environmental Impact Statement for Second Sydney Airport*. (Department of Aviation: Canberra).
A checklist of 71 species in Appendix D arranged alphabetically by genus. Text describes and assesses vegetation. Vegetation map.
WOLLONGONG

243 Kinhill Stearns (1985). Frequency of occurrence of plant species in the vegetation types and in the Allens Creek valley at the proposed airport site at Wilton. In *Draft Environmental Impact Statement for Second Sydney Airport*. (Department of Aviation: Canberra).
A checklist of 350 species in Appendix K arranged alphabetically by genus. Includes frequency data with exotic species marked. Text describes five vegetation communities and assesses their conservation status. Vegetation map.
WOLLONGONG

244 Kohen, J. L., & Edgecombe, A. (1985). Cumberland Plain species list. (Unpub.).
A checklist of 379 species arranged alphabetically by genera. Annotated with collection localities, information on edible parts and other parts used by Aborigines. Exotic species marked.
SYDNEY, WOLLONGONG

245 Linnean Society of New South Wales (1971). Preliminary checklist of plants of Dharug National Park. (Unpub.).
A checklist of 264 species arranged alphabetically by genus with exotic species marked.
SYDNEY

246 McBarron, E. J. (1984). Botanical sampling of cemeteries in Campbelltown, Liverpool, Camden, Narellan and Thirlmere areas. (Unpub.).
A list of 571 species recorded in 18 cemeteries. Arranged alphabetically by genus within growth form types. Non-local and exotic species indicated.
SYDNEY, WOLLONGONG

247 McRae, R. H. D., & Benson, D. H. (1983). Vegetation of Bouddi National Park. (Unpub.).
A checklist of 358 species arranged alphabetically by families and genera

in the major plant groups is given in Appendix 3, annotated with growth form and plant community, with exotic species marked. Extra species recorded by other workers are included in a separate list. Text includes a description of the climate, geology, geomorphology, soils, land uses and six vegetation communities in the study area and discusses several management issues including fire, weed invasion and rare species.
SYDNEY

248 McRae, R. H. D., & Conacher, P. (1980). Vegetation Survey of No. 3 Freeway, Wallarah Creek Interchange to Wallsend. (Unpub.).

Checklists are provided for three sections of the route, with 146, 151 and 150 species respectively, arranged alphabetically by families and genera within the major plant groups. Six vegetation communities are described in the text and the occurrence of species in each is indicated in the lists. Vegetation and location maps. A summarized copy of the report is published in New South Wales Department of Main Roads *Environment Impact Study. Sydney–Newcastle Freeway. Section: Wallarah Creek Interchange to Wallsend.*
SYDNEY

249 Mills, K. (undated). Plant species list for Korrongulla Swamp, Primbee. (Unpub.).

A checklist of 105 species arranged alphabetically by families and genera in the major plant groups. Common names given and exotic species marked. Primbee is near Port Kembla.
WOLLONGONG

250 Mills, K. (1982a). Checklist of the rainforest plants of the Illawarra. Geography Department, Wollongong University. (Unpub.).

Checklist of 178 species arranged in two parts according to growth form (trees and shrubs or creepers, climbers and scramblers), alphabetically by family within the major plant groups. Common names are included.

Also includes checklists for individual sites at Woodhill–Broughton Head, Kangaroo Valley (80 spp.); Upper Brogers Creek, Kangaroo Valley (102 spp.); Upper Burning Palms–Garawarra Range (94 spp.); National Falls, Royal National Park (64 spp.); Bass Point, Shellharbour (77 spp.); Plateau Gully, Barren Grounds Nature Reserve (27 spp.); and Mt Kembla (96 spp.); arranged within growth-form types, alphabetically by genus. Each list accompanied by details of vegetation stucture, geology, aspect, altitude and average rainfall. Extensions of known range indicated.
WOLLONGONG

251 Mills, K. (1982b). Plant species list for the escarpment at Corrimal (end of Glenlea Street). (Unpub.).

A checklist of 105 species arranged alphabetically by families and genera under ferns and flowering plants with common names and exotic species marked. Vegetation profile diagram.
WOLLONGONG

252 Mills, K. (1983a). Plant species list for the Jerrara Dam site, Jamberoo Valley, Kiama, New South Wales. (Unpub.).

A checklist of 165 species listed alphabetically by families and genera under ferns and flowering plants. Common names given and exotic species marked.
WOLLONGONG

253 Mills, K. (1983b). Plant species recorded in the Shellharbour swamp

catchment area. (Unpub.).

A checklist of 67 species arranged alphabetically by genera, each recorded as growing on land-fill, swampland or in remnant forest. Exotic species marked.

WOLLONGONG

254 Mills, K. (1983c). Plant species list for Hicks Creek gully, Asquith Street, Austinmer. (Unpub.).

A checklist of 90 species arranged alphabetically by genera within growth form categories. Exotic species marked. Location map.

WOLLONGONG

255 Mills, K. (1983d). Rainforests of the Illawarra District, New South Wales. Paper presented to Workshop and Open Forum on 'The present and future of Australian Rainforests', Griffith University, Brisbane.

Appendix 1 lists 33 species reaching their northern or southern limit of distribution in the Illawarra District. Text describes the different rainforest communities of the area and discusses their conservation status. Location map.

WOLLONGONG

256 Mills, K. (1984a). Plant species list for the Illawarra rainforests. (Unpub.).

A checklist of 299 species arranged alphabetically by families and genera within the major plant groups. Authorities given and exotic species indicated.

WOLLONGONG

257 Mills, K. (1984b). Preliminary plant list for the Shoalhaven Gorge, incorporating that area adjacent to the Tallowa Dam. (Unpub.).

A checklist of 224 species arranged alphabetically by genera with exotic species marked.

WOLLONGONG

258 Mills, K. (1984c). Vegetation Survey of the Upper Hacking River Catchment. (Unpub.).

Text describes climate, physiography, geology and vegetation communities in the study area, mentioning most abundant species. Conservation status of the area is assessed in relation to Royal National Park. Vegetation map. See ref. 259 (Mills, 1984d).

WOLLONGONG

259 Mills, K. (1984d). Plant lists, Upper Hacking River Catchment Study Area. (Unpub.).

Separate checklists for 40 different sites between Waterfall and Stanwell Tops, each arranged alphabetically by genera with exotic species indicated. Locality map. See ref. 258 (Mills, 1984c).

WOLLONGONG

260 Mills, K. (1985a). Plant species list for vegetation communities in the Otford–Helensburgh area. (Unpub.).

A checklist of 251 species arranged alphabetically by families and genera within the major plant groups. Presence or absence in each of five vegetation communities is recorded and exotic species marked.

WOLLONGONG

261 Mills, K. (1985b). Rainforest plant lists from the Illawarra District, New South Wales. (Unpub.).

A collection of 61 separate checklists arranged in north-south order. Each list includes location, geology, rainfall and altitude of site, date recorded and a brief description of the vegetation. Most lists are arranged alphabetically by genus within growth-form categories. Localities include:
Jibbon Beach, Royal National Park;
Cabbage Tree Basin, Royal National Park;
National Falls, Royal National Park;
Walkers Garden, Royal National Park;
Upper Burning Palms–Garawarra Range, Royal National Park;
Werong Beach, Royal National Park;
Kellys Falls Gully, Stanwell Tops;
Creek east of highway, north of Bellambi Creek;
Mangerton Park, Mangerton;
Mt Kembla Lookout to railway line;
Mt Kembla, west of Wollongong;
Mt Kembla ring track, Illawarra State Recreation Area;
Berkeley Cresent Farm, Berkeley Hills;
Hooka Island, Lake Illawarra;
Gooseberry Island, Lake Illawarra;
Mt Brown, Kanahooka, west of Lake Illawarra;
Mt Warrigal, south of Lake Illawarra;
Wanyambilli Hill;
Wongawilli Colliery;
Upper Avon River Valley;
South Avondale Valley;
Macquarie Pass National Park;
Johnsons Spur, east of Calderwood;
Calderwood (Upper Marshall Mount Creek);
Upper Gallahers Creek, Metropolitan Water Sewerage & Drainage Board Catchment;
Blackbutt Forest Reserve, Shellharbour;
Remnant bush south of Dunsters Lane, Oak Flats;
Whispering Gallery, near Albion Park;
Bass Point, Shell harbour;
Flying Fox Gully, Jamberoo;
Gainsborough Estate, Bombo;
Jerraran Creek Valley;
Bushland remnant south-west of Minnamurra River estuary;
Curramore;
Upper Turpentine Creek, Curramore, Jamberoo Valley;
Portion 20, Knights Hill;
'Fernleigh', Robertson;
Robertson Nature Reserve;
Carrington Falls;
Wild Country Park, Foxground;
Head of Broughton Creek, Foxground;
Plateau Gully, Barren Grounds Nature Reserve;
Headwaters of Brogers Creek;
Upper Brogers Creek;
Highway, 3 km south of Kiama;
Toolijooa Hill, Kiama Municipality;

Baileys Island, Gerroa;
Woodhill–Drawing Room Rocks Track, Barren Grounds;
Woodhill–Broughton Head, Kangaroo Valley;
Devils Glen, Kangaroo Valley;
North end of Blackash Nature Reserve, Cambewarra Range;
Mannings Lookout;
Erith Coal Mine, Bundanoon;
Fairy Bower, Morton National Park;
Sandy Creek, Meryla State Forest;
Tallowa Dam, Shoalhaven Gorge and Bundanoon Creek Gorge;
Creek east of Mt Phillips, Shoalhaven Gorge;
Crooked River and northern end of Seven Mile Beach National Park;
Bens Walk, Nowra;
Bungonia Gorge;
Comerong Island, Shoalhaven River.
WOLLONGONG

262 Mills, K., Muston, R., & Young, A. (1984). Vegetation survey of the Maldon–Dombarton Railway. Part I: Port Kembla to Cordeaux River Bridge site. (Unpub.).

A checklist of 463 species arranged alphabetically by genera in systematically arranged families with annotations relating species to plant communities described in the text. Rare species, exotics and recent name changes are indicated. Location and vegetation maps.

WOLLONGONG

263 Mitchell, J., & Associates (1983). *Lane Cove River State Recreation Area.* (Lane Cove River State Recreation Area Trust: Chatswood).

Includes a checklist of 435 species arranged systematically by families and genera in Appendix 2. Text provides a brief description of the vegetation.

SYDNEY

264 Mount King Ecological Surveys (1984). Flora and fauna survey of the East Hills–Campbelltown Railway. (Unpub.).

One hundred and fifty species listed in alphabetic order by family. Map unit(s) for each species given. Vegetation map.

SYDNEY, WOLLONGONG

265 National Trust of Australia (NSW) (1978). Mosman Municipality — bushland survey. (Unpub.).

About 140 species are listed alphabetically by genus with common names for 14 sites. Weeds, rainforest, wet sclerophyll and dry sclerophyll species are listed separately.

SYDNEY

266 National Trust of Australia (NSW) (1979). Kogarah bushland survey. (Unpub.).

Survey and management recommendations for 16 parks and reserves. About 167 native species are listed alphabetically by family and genus within major plant groups, 52 exotic species are listed separately with common names, occurrence of species in the 16 reserves is indicated.

SYDNEY

267 National Trust of Australia (NSW) (1979). North Sydney bushland survey.

(Unpub.).

Survey for 13 reserves in the municipality. About 113 native species are listed alphabetically under family headings within major plant groups, 52 exotic species are listed separately with common names, occurrence of species in the 13 reserves is indicated.

SYDNEY

268 National Trust of Australia (NSW) (1980a). Narrabeen Lagoon survey. (Unpub.).

Survey with management recommendations for three localities. A checklist of 192 native species arranged alphabetically by families and genera within major plant groups, 35 exotic species listed separately with common names. The occurrence of each species is indicated for three different areas with notes on soils.

SYDNEY

269 National Trust of Australia (NSW) (1980b). Description and management of bushland, West Pennant Hills. (Unpub.).

Survey of area off Castle Hill Road. A checklist of 154 species arranged alphabetically by families and genera within major plant groups, exotics annotated. The occurrence of each species in eight different areas is indicated.

SYDNEY

270 National Trust of Australia (NSW) (1980c). Willoughby Municipality — bushland survey. (Unpub.).

Survey covering bushland reserves in the municipality with reports and management recommendations on thirty-five reserves. A checklist of 212 native species arranged alphabetically by family and genus within major plant groups, 62 exotic species listed separately with common names. The occurrence of each species is indicated for the reserves surveyed.

SYDNEY

271 National Trust of Australia (NSW) (1981a). Woollahra Municipality — bushland survey. (Unpub.).

Survey of five bushland reserves with management recommendations. A checklist of 69 native species arranged alphabetically by family within major plant groups, 52 exotic species listed separately with common names. The occurrence of each species is indicated for five sites.

SYDNEY

272 National Trust of Australia (NSW) (1981b). Hurstville Municipality — bushland survey. (Unpub.).

Discussion and recommendations for 24 sites in the area. About 162 native species listed alphabetically in systematically arranged families under major plant groups, 70 exotic species listed separately with common names. Occurrence of each species is indicated for the 24 reserves surveyed.

SYDNEY

273 National Trust of Australia (NSW) (1981c). Lane Cove River State Recreation Area–Banksia Hill — bushland survey. (Unpub.).

Survey and management recommendations. A checklist of 112 native species listed under systematically arranged families within major plant groups, 29 exotic species listed separately.

SYDNEY

274 National Trust of Australia (NSW) (1981d). Manly Municipality — bushland survey. (Unpub.).

A report on the state of 22 reserves in the municipality. Checklist of 184 native species listed alphabetically under families within major plant groups, 68 exotic species listed separately with common names. Occurrence of each species is indicated for the 22 reserves surveyed.

SYDNEY

275 National Trust of Australia (NSW) (1981e). North Sydney Municipality–Smoothey Park — survey and recommendations. (Unpub.).

Survey and management recommendations. Checklist of 42 native species listed under systematically arranged families within major plant groups, 21 exotic species listed separately.

SYDNEY

276 National Trust of Australia (NSW) (1983). Report on the National Trust survey of the Green Point–Mount Avoca area. (Unpub.).

A checklist of 150 species arranged alphabetically by family and genus within the major plant groups. Common names and the occurrence of each species in respective communities are given. Text describes vegetation communities, compares them with those in Brisbane Water National Park and outlines management problems and recommendations. Location map.

SYDNEY

277 National Trust of Australia (NSW) (1985). List of native plant species — Stanwell Park Coastal Conservation Area. Appendix 1 in Classification Card for Stanwell Park Coastal Conservation Area. (Unpub.).

A checklist of 211 species arranged in systematic order, incorporating tree species recorded by Fuller (1980), ref. 232. Common names given.

WOLLONGONG

278 Outhred, R., Lainson, R., Lamb, R., & Outhred, D. (1985). A floristic survey of Ku-ring-gai Chase National Park. *Cunninghamia* 1: 313–338.

A checklist of 126 indicator species used in the analysis, arranged alphabetically by genera. The text presents a floristic classification scheme for the Park and discusses physiographic and edaphic factors underlying floristic patterns.

SYDNEY

279 Rice, B., & Westoby, M. (1981). Myrmecochory in sclerophyll vegetation of the West Head, New South Wales. *Aust. J. Ecol.* 6: 291–298.

A checklist of 279 species arranged alphabetically by family within the major plant groups for sites used in myrmecochory study. Confirmed and suspected myrmecochores (i.e. plants providing inducements for ants to disperse their seeds) are indicated.

SYDNEY

280 Scarlet, C.A. (1980?). Towra Point lichen species list. (Unpub.).

A checklist of 79 species arranged alphabetically by genus.

WOLLONGONG

281 Selkirk, P., Adamson, D., & Edgecombe, A. (1985). Species list for Greaves Creek Valley, Blackheath. (Unpub.).

A checklist of 242 species arranged alphabetically by genera with exotic species marked.
SYDNEY

282 Stevens, G. N. (1979). Distribution and related ecology of macrolichens on mangroves on the East Australian Coast. *Lichenologist* 11: 293–305.

List of lichen species and their distributions between latitudes 17°S and 38°S on the east coast of Australia. Includes comments on climatic and substrate preferences.
TWEED HEADS, MACLEAN, COFFS HARBOUR, HASTINGS, NEWCASTLE, SYDNEY, WOLLONGONG, ULLADULLA, BEGA, MALLACOOTA

283 South Turramurra Environment Protection (1980). R. A. Buchanan (ed.), *A Plan of Management for South Turramurra Bushland.* (South Turramurra Environment Protection: Sydney).

Separate checklist of 301 native and 49 exotic species arranged systematically by families and genera in the major plant groups. Text describes the history, climate, geology, landscape, fauna and vegetation and discusses management issues.
SYDNEY

284 Sydney Prehistory Group (1983). *In search of the Cobrakal.* Part 1. (National Parks & Wildlife Service: Sydney).

Part 1 includes a vegetation study with a checklist of 328 species for the Georges River area arranged alphabetically by genus, annotated with locality and habitat information. Text describes the vegetation of the area. Vegetation and location maps.
WOLLONGONG

285 Thomas, J., & Benson, D.H. (1985a). Vegetation survey of Ku-ring-gai Chase National Park. (Unpub.).

Includes a checklist of 566 species listed alphabetically by families and genera within the major plant groups. Presence or absence of each species is recorded for 21 plant communities and exotic species are marked. Separate list gives life-form, habit, abundance and source of introduced species. Text describes plant communities, climate, geology, geomorphology, soils, history and land use of the study area and discusses significant vegetation, rare species and management implications. Vegetation map.
SYDNEY

286 Thomas, J., & Benson, D. H. (1985b). Vegetation survey of Muogamarra Nature Reserve. (Unpub.).

A checklist of 393 species arranged alphabetically by families and genera within the major plant groups. Presence or absence is indicated for each plant community and exotic species are marked. Separate list gives common names, locations and life-forms of exotic species. Text describes plant communities, climate, geology, geomorphology, soils, history and land use of the area and discusses significant vegetation, rare species and weed invasion. Vegetation map.
SYDNEY

287 Thomas, J., Burkitt, J., & Benson, D. H. (1984). Vegetation Survey of Bents Basin State Recreation Area. (Unpub.).

A checklist of 358 species arranged alphabetically by families and genera within the major plant groups is given in Appendix 2. Membership of

respective vegetation communities is indicated and exotic species marked. Text includes a description of the geology, physiography and twenty-five vegetation communities and discusses management issues including rare species, fire and weeds. Vegetation map.
SYDNEY

288 Vinicombe, P. (1980). *Prediction and predilection* (National Parks & Wildlife Service: Sydney).
Includes a checklist of 113 species, considered to have been resources for aboriginal populations of the Gosford-Wyong area. List is arranged alphabetically by genera and annotated with information on locality, preparation technique, environment and season of availability.
SYDNEY

289 Webb, J. B. (1981). Vegetation of Spectacle Island, Hawkesbury River, New South Wales. *Cunninghamia* 1: 115–120.
A checklist of 128 species arranged alphabetically by families and genera within the major plant groups. List is annotated with information on rarity and locality, exotic species marked. Text contains brief description of nine vegetation types. Vegetation sketch map.
SYDNEY

290 Wilson, N. C. (1984). The plant communities of the saltmarshes of the Sydney region. B.Sc. (Hons) Thesis, School of Botany, University of N.S.W.
Includes a checklist of 148 species arranged alphabetically by families and genera under flowering plants, algae and mosses with notes on occurrence, environment, distribution and records of previous authors. Exotic species marked.
SYDNEY, WOLLONGONG

291 van der Velde, J. T., & King, R. J. (1984). The subtidal seaweed communities of Bare Island, Botany Bay. *Wetlands* 4: 7–22.
A checklist of 42 species is presented in Figure 5. Text discusses patterns in algal communities at this site.
SYDNEY

For additional lists also relevant to the Central Coast, see ref. 307 (Bowden, 1962); ref. 310 (Fallding & Benson, 1985); ref. 316 (Keith & Benson, 1985); and ref. 319 (Vermeulen, 1985).

SOUTH COAST

292 Boyd, C. O. (1970). Montague Island flora list, extracted from Rodway's diary. (Unpub.).
A checklist of 36 species.
BEGA

293 May, V. (1981). Long term variation in algal intertidal floras. *Aust. J. Ecol.* 6: 329–343.
Checklists for Plantation Point, Jervis Bay (100 species), and Ulladulla Headland, Ulladulla (68 species) arranged alphabetically by genus. Text discusses variations in the abundance of algal species and the factors that may influence this.
ULLADULLA

294 May, V. (1985). Observations on algal floras close to two sewerage outlets.

Cunninghamia 1: 385–394.

Checklists of 37 and 35 species respectively for Ulladulla and Plantation Point arranged alphabetically by genus with data on changes in abundance and periods of occurrence during 1976–1979. Frequency data are presented for species found nearest the sewerage outlets at both sites. Text discusses the effect of sewerage outfall on algal populations.

ULLADULLA

295 Mills, K. (1982). Species list for Meryla–Yarrunga Creek–Wombat Hill. (Unpub.).

A checklist of 168 species arranged alphabetically by genus. Annotations for species observed flowering and fruiting. Exotic species marked.

WOLLONGONG

296 Mills, K. (1985). Vegetation survey of the proposed Shoalhaven–Moruya 132 kv No. 2 transmission line. Electricity Commission of New South Wales. (Unpub.).

Includes four checklists for different sections of the route with 361, 378, 218 and 227 species respectively. Species are arranged alphabetically by families and genera within the major plant groups and are annotated with habitat data. Text describes study area and its plant communities, discusses vegetation patterns, the significance of species and communities, and details recommendations.

WOLLONGONG, ULLADULLA

297 National Parks & Wildlife Service (Nowra–Goulburn District) (1984). Morton Park plants. (Unpub.).

A compilation of lists and information from Miss Cosh, Mr R. Oliver, Mrs R. Roxburgh and ref. 325 (Olsen, 1982). Combined list containing 742 species arranged alphabetically by families and genera within the major plant groups with common names and habit information.

WOLLONGONG, ULLADULLA

298 Outhred, R. (1984). Vascular plants of the Wadbilliga National Park — Provisional species list. New South Wales Institute of Technology. (Unpub.).

A list of 465 species arranged alphabetically by genus within families. Includes notes on rarity for some species. Introduced species marked.

BEGA

For additional lists also relevant to the South Coast see ref. 189 (Adam, 1981); ref. 257 (Mills, 1984b); ref. 282 (Stevens, 1979).

NORTHERN TABLELANDS

299 Fisher, H. J. (1985). The structure and floristic composition of the rainforest of the Liverpool Range, New South Wales, and its relationships with other Australian rainforests. *Aust. J. Ecol.* 10: 315–325.

A checklist of 115 species arranged systematically by families and genera with life-form is given in the appendix. Text describes the vegetation and discusses species composition and distribution in relation to other rainforest stands.

TAMWORTH

300 National Parks & Wildlife Service (undated). *Mount Kaputar National Park*

Plan of Management (N.P.W.S.: Sydney).

Vegetation section contains descriptions of eight vegetation types, mentioning typical species.

MANILLA

301 Patrick, W. (1979). Mount Kaputar National Park — a checklist of plants. (Unpub.).

A checklist of 538 species arranged alphabetically by families and genera within the major plant groups. Compiled and updated from lists by Gwen Harden. Common names and habitat notes given for some species.

MANILLA

302 Turner, J. C. (1976). An altitudinal transect in rainforest in the Barrington Tops area, New South Wales. *Aust. J. Ecol.* 1: 155–174.

Includes a checklist of 58 species occurring on the transect. List is arranged systematically and includes information on growth form, frequency and vegetation group. Text discusses altitudinal distribution patterns.

SINGLETON

For additional lists also relevant to the Northern Tablelands see ref. 194 (Archer, 1980); ref. 340 (Williams, 1979).

CENTRAL TABLELANDS

303 Anon. (1981). *Bryophytes of South-eastern Australia.* Field Excursion Handbook No.34. (XIII International Botanical Congress: Sydney).

Contains lists of bryophytes found at Mount Wilson Waterfall Reserve (51 species) and Zig Zag Bend, Mt Wilson (22 species) in the Blue Mountains, arranged alphabetically by genus within the major groups. Text describes the area and lists the main tree species.

SYDNEY

304 Armstrong, J. (1981). *A Botanical excursion to the Blue Mountains.* Field Excursion Handbook No. 19. (XIII International Botanical Congress: Sydney).

A checklist of 163 genera mentioned in the text arranged alphabetically with family names in brackets. Text describes the history, geology, geomorphology and vegetation for a number of sites. Brief lists of main species are given for Narrow Neck, Wentworth Falls, Evans Lookout, Beauchamp Falls, Greaves Creek, Neates Glen, Point Pilcher Swamp, Mount Banks, Mount Wilson, Jenolan Caves, Boyd Plateau and Kanangra Walls. Location map.

SYDNEY

305 Benson, D. H. (1980). Vegetation of Jamison Creek, Wentworth Falls. (Unpub.).

An incomplete list of 35 native and eight exotic species accompanied by a brief description and assessment of the vegetation.

SYDNEY

306 Black, D. (1976). An exploratory survey of the vegetation of the Boyd Plateau. M.Sc. Thesis, Sydney University.

A checklist of 174 species arranged by families in systematic order. Text contains description of plant communities and their associated geology and

topography. Photographs and vegetation map. A summary has been published in 1982 in *Vegetatio* 50: 93–111.
BATHURST, SYDNEY, GOULBURN, WOLLONGONG

307 Bowden, I. (1962). Orchids of the Blue Mountains, N.S.W. *Australian Naturalist* 12: 11–20.
A checklist of 155 orchid species occurring on the mostly sandstone area of the Grose River Catchment and south to the Coxs River accompanied by locality notes for each species, sketches, and comments on interesting records for the area.
SYDNEY

308 Coveney, P. J. (1970). Investigation report for Copperhannia Nature Reserve. (Unpub.).
Includes a checklist of 26 main species and a brief description of the vegetation.
BATHURST

309 Coveny, R. G. (1977). Winburndale Nature Reserve. A plant checklist (Gulf Stream to Winburndale Reservoir). (Unpub.).
A checklist of 156 species arranged alphabetically by genus. Exotic species marked.
BATHURST

310 Fallding, H. B., & Benson, J. S. (1985). Natural vegetation and settlement at Macquarie Pass, Illawarra Region, New South Wales. *Cunninghamia* 1: 285–311.
A checklist of c. 400 species arranged alphabetically by families and genera in the major plant groups, annotated with vegetation community membership, exotic species marked. Text describes 10 vegetation communities, climate, topography, ecology, soils and history of settlement in the area. Vegetation map.
WOLLONGONG

311 Gregson, J. (1902–3). Lichens collected at Mount Wilson. (Unpub.).
46 species listed with authorities, determined by E. Cheel.
SYDNEY

312 Hind, P. (1984). A preliminary checklist of rainforest flora below the dam on Mount Tomah. (Unpub.).
Checklist of 60 species for Mount Tomah Botanic Garden, an annexe of the Royal Botanic Gardens, Sydney. Exotic species indicated.
SYDNEY

313 Keith, D. A. (1984a). Floristic list for swamp near Kedumba Gate, Kings Tableland. (Unpub.).
A list of 19 species arranged alphabetically by families and genera.
SYDNEY

314 Keith, D. A. (1984b). Floristic list for Murphys Glen. (Unpub.).
A list of 33 species arranged alphabetically by families and genera.
SYDNEY

315 Keith, D. A. (1984c). Floristic list for heath adjacent to the Deer Park, Kings

Tableland. (Unpub.).
A list of 48 species arranged alphabetically by families and genera.
SYDNEY

316 Keith, D.A., & Benson, D.H. (1985). Species list for the Katoomba 1:100 000 vegetation map sheet. (Unpub.).
A list of about 650 species arranged alphabetically by families and genera, annotated with plant communities. List is updated as further data is collected.
SYDNEY

317 Lee, R. (1980?). Flora list — Winburndale Nature Reserve. (Unpub.).
A checklist of 313 species arranged alphabetically by families in the major plant groups. A compilation of lists for the area including common names, location and source of identification, for each species. Exotic species marked.
BATHURST

318 National Parks & Wildlife Service (undated). Species list for Evans Crown Nature Reserve. (Unpub.).
An incomplete checklist of 47 species arranged alphabetically by families and genera with some common names given.
BATHURST

319 Vermeulen, R. (1985). Rainforest of the Blue Mountains and Hawkesbury. Part 2 — Floristic list of rainforests in the Wollemi and Blue Mountains. *Hawkesbury Flora* 7: 20–31.
A checklist of 143 species arranged alphabetically by families and genera in the major plant groups. Includes trees and shrubs only. Compiled from a list by Alex Floyd with additional annotations on growth form, height, flowering time, flowers and fruit and rainforest structural formations.
SYDNEY

For additional lists also relevant to the Central Tablelands, see ref. 194 (Archer, 1980); ref. 203 (Benson, 1984b); ref. 295 (Mills, 1982); ref. 297 (National Parks & Wildlife Service, 1984).

SOUTHERN TABLELANDS

320 Benson, J. S. (1982). Plant species identified during a walk in the Mount Tinderry Area — western side of Tinderry Range. (Unpub.).
A checklist of 99 species, the families and genera arranged alphabetically within the major plant groups, with life-form and abundance information. Exotic species marked.
CANBERRA

321 Elix, J. A. (1981). *Sub-alpine and temperate rainforest lichens*. Field Excursion Handbook No. 30. (XIII International Botanical Congress: Sydney).
Contains a checklist of lichens for Mount Aggie, A.C.T. (40 species), and the Monga area (34 species) arranged alphabetically by genus. Text includes site notes.
CANBERRA

322 Helman, C. E., & Gilmour, P. M. (1985). Treeless Vegetation above 1000 metres altitude in the A.C.T. (Unpub.).

Includes a checklist of 408 species arranged alphabetically by families and genera within the major plant groups. Annotated with plant communities. Text describes climate, geology, topography, soils and vegetation of site, and discusses vegetation patterns and management implications.
CANBERRA

323 Ingwersen, F. (1985). *Tidbinbilla Nature Reserve vegetation.* (A.C.T. Parks and Conservation Service, Canberra).
No list. Text describes 15 plant communities with major species, altitudinal range and comments on distribution. Vegetation map.
CANBERRA

324 Mills, K. (1984). Plant species recorded in the Majors Creek study area. (Unpub.).
A checklist of 46 species arranged alphabetically by families and genera with common names and exotic species marked.
CANBERRA

325 Olsen, I. (1982). Plant species list for the Budawang Ranges. Pp. 216–240 in The Budawang Committee (eds), *Pidgeon House and beyond, a guide to the Budawang Range and environs.* (The Budawang Committee: Eastwood).
A checklist of 429 species arranged alphabetically by families within the major plant groups. Notes are provided on the physiography, climate and soils of the study area. The list is annotated with typical heights, flowering time, associations, habitat, distribution and abundance of each species. See ref. 328 (Pickard, 1982).
ULLADULLA

326 O'Neill, M. (1984). Some flora of Bungonia State Recreation Area. (Unpub.).
A checklist of 230 species which have been photographed in Bungonia State Recreation Area, arranged in alphabetical order.
GOULBURN, WOLLONGONG

327 Parris, M., & Wimbush, D. J. (1974). Alpine plants — the alpine plants of the Kosciusko National Park. *Australian Plants* 7: 351–370.
No list, text describes nine plant communities and their habitats, mentioning main species.
TALLANGATTA, BEGA

328 Pickard, J. (1982). Vegetation of the Budawang Range. Pp. 241–249 in The Budawang Committee (eds), *Pidgeon House and beyond, a guide to the Budawang Range and environs.* (The Budawang Committee: Eastwood).
Brief descriptions of 16 vegetation communities are given including dominant species. Vegetation map. See ref. 325 (Olsen, 1982).
ULLADULLA

329 Ramsay, H. P., & Streimann, H. (1984). Mosses and their distribution in the Australian Capital Territory. *Telopea* 2: 559–574.
Checklist of 180 species, the genera arranged alphabetically within systematically arranged families. Local, state and national distributions given. Text provides habitat descriptions. Location map.
CANBERRA

330 Telford, I. R. (1981). *Wilderness walk, Morton National Park.* Field Excursion Handbook No. 18/2. (XIII International Botanical Congress: Sydney).

Contains a checklist of 594 species collected from the northern Budawang Range and held at the National Botanic Gardens, Canberra. List is arranged alphabetically by families and genera within the major plant groups and contains habitat information for each species. Text describes the climate, geology and landforms, soils and vegetation. Location and geological maps.

ULLADULLA

331 Thompson, J. (1981). A key to the plants of the subalpine and alpine zones of the Kosciusko region. *Telopea* 2: 219–297.

A key to vascular plants of this region with brief habitat and distribution notes. Also contains an account of recent history of the area and comments on the origin and distribution of the flora.

TALLANGATTA, BEGA

332 Thompson, J., & Gray, M. (1981). A checklist of subalpine and alpine plant species found in the Kosciusko region of New South Wales. *Telopea* 2: 299–346.

A checklist of 455 species, the genera arranged alphabetically within systematically arranged families. Representative localities and altitudes listed for each species.

TALLANGATTA, BEGA

333 Ward, J. E., & Ingwersen, F. (1979). *A checklist of vascular plant species in the Tidbinbilla Nature Reserve.* Conservation Memoranda No. 8 (Department of the Capital Territory: Canberra).

A checklist of 352 species arranged in alphabetical order by family and genus. Common names given and exotic species marked.

CANBERRA

334 Ward, J. E., & Ingwersen, F. (1984). *Checklist of vascular plant species in the Tidbinbilla Nature Reserve.* Conservation Series No. 8 (Australian Capital Territory Parks & Conservation Service: Canberra).

A checklist of 475 species arranged alphabetically by families and genera within the major plant groups. Annotations are made for exotic species, non-indigenous native species, noxious exotic species, protected species, endangered species and unsubstantiated records of Burbidge & Gray (1970), *Flora of the Australian Capital Territory.* Common names given.

CANBERRA

335 Willis, J. H., & Roger, K. C. (1975). Vascular flora of White Rock Mountains (source of Genoa River near Rockton, New South Wales) and North-West Slopes to Nalbaugh Pine Plantation. (Unpub.).

A checklist of 218 species, arranged alphabetically in families and genera within the major plant groups.

MALLACOOTA

336 Willis, J. H. (1981). Plants of Tinderry Mountains, South-East New South Wales (east of Michelago). (Unpub.).

A combined list from 2 localities (crest of South Tinderry Peak south-eastwards to flats along Roberts Creek, and summit of main Tinderry Peak and its western escarpments to edge of forest on Tea Tree Creek).

Contains 191 species in systematically arranged families within the major plant groups. Exotic species marked.
CANBERRA

337 Wimbush, D. J., & Costin, A. B. (1973). *Vegetation mapping in relation to ecological interpretation and management in the Kosciusko alpine area.* CSIRO Division of Plant Industries, Technical Paper No. 32. (CSIRO: Melbourne).
A description of 12 plant communities with a list of the dominant species. Vegetation map.
TALLANGATTA, BEGA

For additional lists also relevant to the Southern Tablelands, see ref. 297 (National Parks & Wildlife Service, 1984).

NORTH WESTERN SLOPES

338 Fox, B. J., & Briscoe, D. A. (1980). *Pseudomys pilligaensis*, a new species of murid rodent from the Pilliga Scrub, Northern N.S.W. *Aust. Mammal.* 3: 109–126.
Checklist of 113 species at seven mammal capture sites is presented in Appendix 2, arranged in alphabetical order.
NARRABRI

339 Mitchell, P. B., Rundle, A. S., & students (1982). Land Systems of the Pilliga Region N.S.W. Macquarie University. (Unpub.).
Species list from all available literature, not field checked. Common names and some habitats given. Map.
NARRABRI

340 Williams, A.R. (1979). *A survey of natural pastures in the North-West Slopes of New South Wales.* Technical Bulletin 22. (Department of Agriculture: Sydney).
A checklist of 550 species, the families and genera listed alphabetically, with abundance and soil type information. Text contains descriptions of vegetation communities and discussion of their relationships with soil type, climate, topography and land use.
INVERELL, MANILLA, TAMWORTH

CENTRAL WESTERN SLOPES

341 Croft, K., & Associates (1984). Botany, wildlife and ecological studies. In *Hunter Valley No. 2 Mine Environmental Impact Statement.* Vol. 2. Supporting Studies. (Coal & Allied Operations Proprietary Limited: Newcastle).
A checklist of about 130 species at the study site, arranged alphabetically by family and genus. Common names, growth form and local abundance given for each species. Text describes six vegetation communities and discusses their conservation status.
SINGLETON

342 Dorman, H. C. (1972). Lees Pinch–Murrumbo flora and bird list. *Hunter Natural History* 4: 269.
A checklist of 338 species arranged in systematic order. Rare and unusual species annotated. Details of locality and collector given.
SINGLETON

343 Fallding, H. B. (1985). The native plants of the Wyalong district and the contribution of Anne Mitchell (1904–1981). (Unpub.).

A checklist of 337 species collected by Anne Mitchell, arranged alphabetically by families and genera. Collection notes include common name, locality, date and habitat. Text describes the area, its climate, geology and seven vegetation types with comments on three rare species.

FORBES

344 Ingram, C. K. (undated). Flora of Lees Pinch, Upper Goulburn River, N.S.W. (Unpub.).

A checklist of 273 species arranged in systematic order with common names. Records for Lees Pinch and Bylong Valley noted.

SINGLETON

345 McRae, R. H. D., & Cooper, M. G. (1985). Vegetation of the Merriwa area, New South Wales. *Cunninghamia* 1: 351–369.

A checklist of 306 species arranged alphabetically in families and genera in the major plant groups, annotated with vegetation community and growth form with exotic species marked. Text describes six vegetation communities, climate, geology, geomorphology, soils and land use and comments on vegetation patterns, rare species and communities. Vegetation map.

SINGLETON

346 National Parks & Wildlife Service (undated). Species list for Conimbla National Park. (Unpub.).

Data sheets listing 163 species with information on habitat, abundance and flowering and seeding times.

BATHURST

347 National Parks & Wildlife Service (undated). Species list for Currumbenya Nature Reserve. (Unpub.).

Data sheets listing 152 species with information on habitat, abundance, flowering and seeding times.

FORBES, BATHURST

348 National Parks & Wildlife Service (undated). Species list for Weddin Mountains National Park. (Unpub.).

Data sheets listing 274 species arranged alphabetically by families and genera with information on habitat, abundance and flowering times. Some common names given.

FORBES

349 Soil Conservation Service of New South Wales (1982). *Wellington Technical Manual* (Soil Con.: Sydney).

Descriptions of eleven plant communities mentioning only the main species. Vegetation map.

DUBBO

350 Thompson, L., Brickhill, J., Fallding, H., & Johnston, J. (1978–1979). Flora of Ingalba Nature Reserve. (Unpub.).

A checklist of 84 species arranged alphabetically by family and genus within the major plant groups. Common names given and exotic species marked.

COOTAMUNDRA

SOUTH WESTERN SLOPES

351 Keith, D. A., & Pellow, B. J. (1985). Preliminary species list for Burrinjuck Dam area. (Unpub.).

A checklist of about 100 species arranged alphabetically by families and genera within the major plant groups. Locality information given for eight sites, exotic species marked.

GOULBURN

352 Mulham, W. E., & Jones, D. E. (1981). Vascular plants of the Riverine Plain of New South Wales — Supplementary List. *Telopea* 2: 197–213.

A list of 200 plant collections, the genera arranged alphabetically within systematically arranged families. Collection notes include common names, detailed locality, distribution, abundance and value to stock. Exotic species indicated. Supplements the list of Leigh & Mulham (1977) *Telopea* 1: 225–293.

BALRANALD, BOOLIGAL, IVANHOE, DENILIQUIN, HAY, WANGARATTA, JERILDERIE, NARRANDERA, CARGELLIGO, NYMAGEE

NORTH WESTERN PLAINS

353 Cunningham, G. M., & Milthorpe, P. L. (1981). The vascular plants of five exclosure sites in western New South Wales. *Cunninghamia* 1: 23–34.

A checklist of 401 species arranged alphabetically by family and genus. Site shown for each. Presence of each species at each site is recorded and exotic species marked. Text describes the sites and comments on the effect of fencing on vegetation communities.

MANARA, BOOLIGAL, IVANHOE, CARGELLIGO, NYMAGEE, COBAR, FORBES

354 Cunningham, G. M., Mulham, W. E., Milthorpe, P. L., & Leigh, J. H. (1981). *Plants of Western New South Wales* (Soil Conservation Service of New South Wales & Government Printing Office: Sydney).

Descriptions of about 2000 species arranged alphabetically by genus within systematically arranged families. Notes on habitat, distribution, growth characteristics and responses to seasonality and grazing. Photographs and common names provided.

355 Moore, C. W. E. (1984). *Annotated checklist of the vascular plants in part of north-western New South Wales.* CSIRO Division of Land Resources Management Technical Memorandum 84/30. (CSIRO: Canberra).

A checklist of 784 species arranged alphabetically by genus in systematically arranged families. Notes for each species include collecting numbers for specimens held at Herbarium Australiense, localities and habitat information. Text contains descriptions of climate, topography and plant communities.

NYNGAN, BOURKE, BARNATO, WILCANNIA, COBAR, LOUTH, YANTABULLA

356 Thompson, J. (1968–1970s). A list of plants collected in the Brewarrina area. (Unpub.).

A checklist of 226 species arranged systematically in families and genera with collection notes and numbers.

ENNGONIA, BOURKE

For additional lists also relevant to the North Western Plains, see ref. 338 (Fox &

Briscoe, 1980); ref. 339 (Mitchell *et al.*, 1982); and ref. 340 (Williams, 1979).

SOUTH WESTERN PLAINS

For lists relevant to the South Western Plains, see ref. 354 (Cunningham *et al.*, 1981).

NORTH FAR WESTERN PLAINS

357 Anon. (1970–71). Checklist of flora identified at Mootwingee Historic Site. (Unpub.).

Checklist of 174 species, the families and genera arranged in systematic order, with reference numbers and brief notes on habit, habitat and common names.

BROKEN HILL

358 Emerick, J. O. (1985). *Environmental Impact Statement for a high temperature incinerator at The Gorge* (Rinex Environmental Services Pty Ltd: Sydney).

A checklist of 77 species is given in Appendix 6, arranged alphabetically by genera with authorities, families and common names. Text describes and assesses vegetation of The Gorge, near Broken Hill.

BROKEN HILL

359 Mahood, I. T. (undated). Plant list for Gnalta National Park and Coturaundee Nature Reserve. Compiled from an Investigation Report by National Parks & Wildlife Service, Soil Conservation Report, and collections of I. Mahood. (Unpub.).

Checklist of 106 species with common names, the genera arranged alphabetically in systematically arranged families with references to Black's *Flora of South Australia*. Accompanied by a detailed description of three major plant communities.

BROKEN HILL, WILCANNIA, COBHAM LAKE, WHITE CLIFFS

360 Pickard, J. (1978). Vegetation map of North Western New South Wales. Royal Botanic Gardens, Sydney. (Unpub.).

68 vegetation associations with structural forms. Dyeline map 1:1 000 000 and brief accompanying notes.

MILPARINKA, URISINO, YANTABULLA, COBHAM LAKE, WHITE CLIFFS, LOUTH, BROKEN HILL, WILCANNIA, BARNATO

For additional lists also relevant to the North Far Western Plains, see ref. 353 (Cunningham & Milthorpe, 1981); ref. 354 (Cunningham *et al.*, 1981); and ref. 363 (Lubeke *et al.*, 1980).

SOUTH FAR WESTERN PLAINS

361 George, I. (1972). Wattles of the Mildura area. *Sunraysia Naturalists Research Trust, Ninth Report*: 24–27.

18 *Acacia* species found near Mildura divided into five taxonomic groups, distribution, localities, habitat, common names.

MILDURA

362 Henshall, T. S. (1972). A checklist of the flora of the Kings Billabong Area. *Sunraysia Naturalists Research Trust, Ninth Report*: 31–37.

A list of 250 species arranged alphabetically by genus in systematically arranged families. Common names given and exotic species marked.

MILDURA

363 Lubeke, E., Lubeke, J., Petersen, I., Reeves, P., Wall, J., & Wall, B. (1980). Broken Hill : Field Naturalists Club of Victoria 25/8/79 to 6/9/79. *The Victorian Naturalist* 97: 222–224.

Contains a list of about 70 species noted flowering between Mildura and Broken Hill. Includes common names and brief locality notes.

MILDURA, ANABRANCH, MENINDEE, BROKEN HILL

For additional lists also relevant to the South Far Western Plains, see ref. 354 (Cunningham *et al.*, 1981).

NEW SOUTH WALES — GENERAL

364 Drake, W. E., & Specht, R. L. (1980). Reference list — heath/sclerophyll vegetation species lists. Prepared for the Australian Heritage Commission. (Unpub.).

A record of comprehensive floristic lists: 14 from Queensland, 11 from New South Wales, 11 from Victoria, 11 from Tasmania, 10 from South Australia, 2 from Northern Territory and 8 from Western Australia and a list of poorly recorded localities.

365 Ramsay, H. P. (1984). Census of New South Wales mosses. *Telopea* 2: 455–534.

Checklist of 527 species, arranged alphabetically by genus in systematically arranged families with distribution information. Also contains list of references.

366 Ramsay, H. P. (1984). Phytogeography of the mosses of New South Wales. *Telopea* 2: 535–547.

List of species apparently endemic to New South Wales, arranged alphabetically by genus in systematically arranged families with distribution information. Rare species indicated. Text discusses relationships, distribution patterns and endemism.

367 Sammy, N. (1980a). Records of New South Wales lichens housed in the Cryptogamic Herbarium, British Museum (Natural History), London. (Unpub.).

A checklist of 20 species with collectors' names, localities, dates and annotations, and corrected taxa with determinavits where appropriate. Type specimens marked. Mostly eastern New South Wales. Includes a list of lichen collectors and references.

368 Sammy, N. (1980b). Records of New South Wales lichens housed in the Herbarium of the Conservatoire at Jardin Botaniques, Geneva. (Unpub.).

A checklist of 69 species with collectors' names, localities, dates and annotations, and corrected taxa with determinavits where appropriate. Type specimens marked. Mostly eastern New South Wales. Includes a list of lichen collectors and references.

369 Sammy, N. (1980c). Collections of New South Wales lichens housed at the Adelaide Herbarium. (Unpub.).

A list of eight collections of the species *Parmelia amphixantha* with collectors' names, date and location.

Acknowledgments

Thanks are due to Peter Wilson for his assistance with collation and Doug Benson for his advice and comments on the manuscript. I would also like to thank authors who made their unpublished work available through the Royal Botanic Gardens Library.

The effect of drought and position in the dam on the algal composition of two dams in New South Wales

V. May

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Abstract

May, V. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1988. The effect of drought and position in the dam on the algal composition of two dams in New South Wales. Cunninghamia 2(1): 75–84. — The effect of drought and position in the dam on algal composition was investigated at two dams in New South Wales.

Introduction

Phytoplankton studies were carried out on two dams in the Hunter River Valley, New South Wales, to study the effects of drought and position in the dam on the algal composition. Water samples were made at 2–4 week intervals from five stations in Lostock Dam (32°10′S; 151°05′E) (Figure 1) between May 1979 and April 1983, and from five stations in Glenbawn Dam (32°04′S; 150°55′E) (Figure 2) between September 1978 and January 1982. The period of drought was 1980–1981, and the effects were more severe at Glenbawn. Methods are as for May & Powell (1986). Full data sets are held by the Library, National Herbarium of New South Wales, Royal Botanic Gardens, Sydney.

Results and Discusssion

Number and distribution of taxa[1]

Of the 68 algal taxa recorded from Lostock Dam, 36 were common, 27 rare and five were found only as drift material (Table 1, Frequency).

In Glenbawn Dam, 34 taxa were recorded as common, 20 as rare and four as drift material (a total of 58 algal taxa) (Table 1, Frequency).

Thirty of the common taxa were found in both dams though abundance data for these taxa varied greatly (Table 1, Abundance)[2]. It was particularly noticeable that the potentially toxic algae *Anacystis* and *Anabaina* were not prevalent in Lostock, though often abundant in Glenbawn. These differences in abundance are explained probably by the high rate of flow and low retention time shown by the water in Lostock, compared with Glenbawn and other dams (Chaffey, May & Powell, 1986, and Carcoar, May, 1988) which all show the same high abundance ratings of toxic algae, low rate of flow and high retention time.

Seasonal growth

Seasonal appearance of taxa in Lostock was variable from year to year. In Glenbawn, some taxa recurred annually, while others showed a seasonal

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[1] Where only one species of a genus is reported, the generic name alone is used. A full list of species names and authorities is given in Table 1.

[2] This high number of taxa common in both dams is not surprising considering the wide distribution of many freshwater algae.

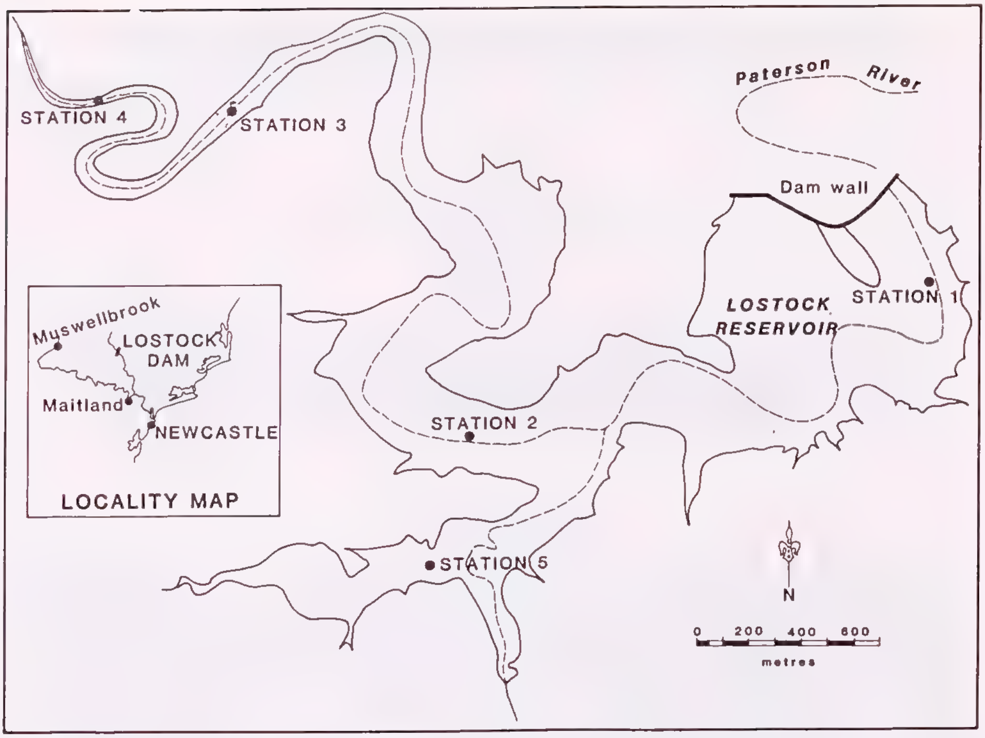

Figure 1. Location of Lostock Dam in Hunter River Valley, showing locations of collecting stations.

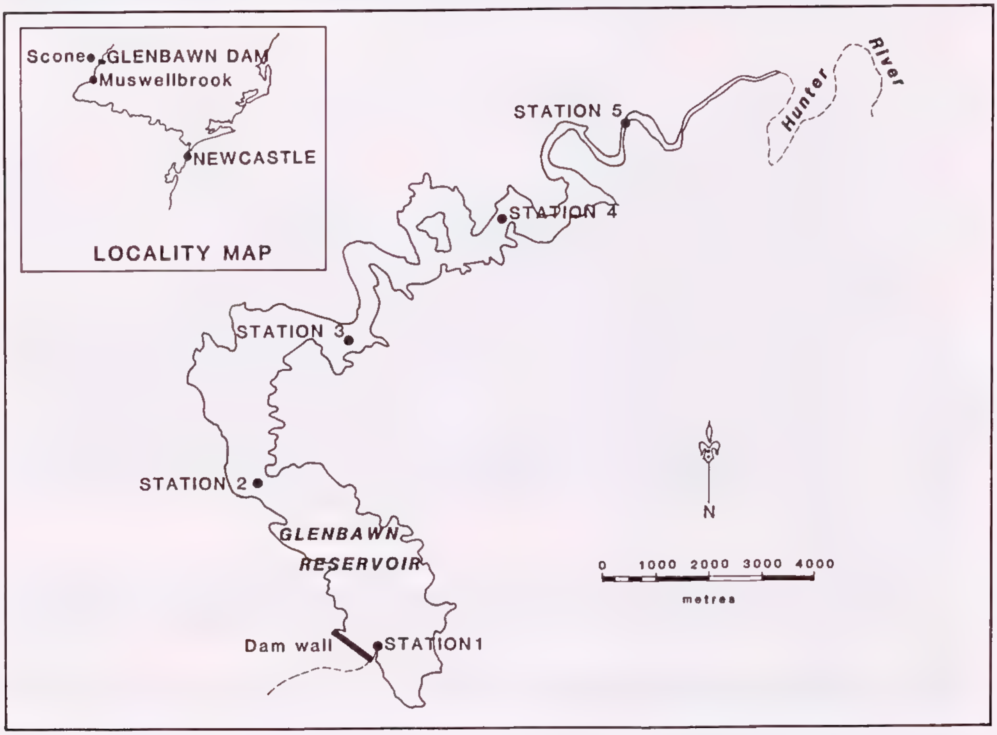

Figure 2. Location of Glenbawn Dam in Hunter River Valley, showing locations of collecting stations.

development in the first two years, but less so in the third (drought). This decreased seasonality in drought time was also recorded in the Peel River (May & Powell, 1986). The lack of precise seasonality in Glenbawn and Lostock is probably due to variations in year-to-year temperatures and inorganic nutrients, though many species tend to occur more often in summer (Table 1, Seasonal Effect).

Drought

The major effect of drought (1980–81) in Lostock (Table 1, Effect of drought) was immediately to increase the frequency of 22 common taxa, with a further three taxa remaining near their maximum frequency during the drought. Nine taxa continued to show increased frequency in the year following the drought. Those remaining of the original taxa showed a slight or marked reduction in frequency during the drought or were erratic.

In eight common taxa in Glenbawn, frequency stayed constant or increased with drought and continued at high or even increasing levels in the prolonged drought[3]. In another 10 species the frequency at first increased with drought, then decreased with prolonged drought (Table 1, Effect of drought). In contrast, 12 taxa decreased with drought and continued at low or even decreasing frequencies thereafter, while another two decreased in frequency with drought and later increased with prolonged drought. Two taxa showed less clear changes.

Fifteen of the 30 common taxa occurring in both dams increased in frequency of occurrence with the onset of drought, two others also increased, but, in Glenbawn, only after an initial decrease. Eight other taxa decreased in both dams and one showed no significant change (Table 1, Effect of drought). Thus, only four taxa showed contrasting behaviour, increasing in frequency at the onset of drought at Lostock, but decreasing at Glenbawn.

There appears to be little relationship between the after-effects of drought shown at Lostock and the response of various species to prolonged drought at Glenbawn (Table 1, Effect of drought). Although more taxa showed high abundance ratings more often in drought time, only two taxa (*Sphaerocystis* and *Peridinium*) became abundant in both dams during drought or prolonged drought. The number and occurrences of rare species increased with drought in both dams, but then decreased with prolonged drought at Glenbawn. Drift species were less frequent in times of poor water flow.

Comparing Carcoar (May, 1988), Lostock and Glenbawn, six common taxa (*Botryococcus*, *Closterium aciculare*, *Ceratium*, *Microcoleus*, *Pediastrum duplex* and *Trachelomonas armata*) increased or extended their range in some way with the onset of drought in all three dams; only *Melosira varians* decreased in all three.

Position of station

Some taxa were more frequent upstream and probably represent what have been termed 'fluvial' species, while those with lower frequency upstream are regarded as 'lacustrine' species[4].

Nine common taxa appeared as fluvial species in both dams while another eight were lacustrine (Table 1, Behaviour). Four taxa had contrasting behaviour; some species showed definite behaviour in one dam, indefinite in the other. A comparison of common lacustrine and fluvial taxa found in all or combinations of Chaffey, Carcoar, Lostock and Glenbawn Dams is shown in Table 2.

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[3] *Anacystis* is included here; already very high in freqency, it increased progressively in abundance.

[4] *Anabaina* and *Euglena* sp. 2 are also considered as fluvial in Glenbawn dam, since they occurred in abundance or high abundance much more frequently in Stations 4 and 5.

Table 1: Frequency of occurrence, seasonality, abundance, fluvial or lacustrine behaviour and effect of drought on species recorded from Lostock (LO) and Glenbawn (GL) Dams.

Taxon	1 Frequency		2 Seasonal effect		3 Abundance		4 Behaviour		5 Effect of drought		
Dam:	LO	GL	LO	GL	LO	GL	LO	GL	LO	GL	Comp.
Actinastrum hantzschii Lag.	C	C	Jan	Nov, Jan, Feb	1	—	F	F	I+	D+	X
Agmenellum thermale (Kuetz.) Drouet & Daily	R	—	—	—	—	—	—	—	—	—	—
Anabaina circinalis Rabenh.	C	C	Jan–Apr, Oct	Jan	1	2	L	F	(D)	D+	D
Anacystis cyanea (Kuetz.) Drouet & Daily (= *Microcystis aeruginosa* Kuetz.)	C	C	Feb, Apr, May, Oct	Jan–Feb, Apr, Jun–Aug	—	2	L	L	I+	I+	I
Ankistrodesmus falcatus (Corda) Ralfs	C	C	May, Jul, Aug, Oct	Oct, Dec	—	1	F	L	(I)	i+	I
Aphanizomenon (ecophene of *Calothrix parietina* (Naeg.) Thuret)	R	C	—	Jan	—	1	—	L	—	D+	—
Asterionella sp.	C	—	Dec	—	2	—	L	—	(I)	—	—
Botryococcus braunii Kuetz.	C	C	Dec	Jan, Feb, Jun	2	—	L	L	(I)	I+	I
Ceratium hirundinella (O.F. Muell.) Dujardin	C	C	Apr, Jun	Apr, Jun	1	1	L	L	(I)	D+	X
Chlamydomonas sp.	—	R	—	—	—	—	—	—	—	—	—
Chodatella chodati (Bern.) Ley.	R	—	—	—	—	—	—	—	—	—	—
C. subsalsa Lemm. (*Lagerheimia*)	R	C	—	Jan, Dec	—	2	—	—	—	(I)	—
Cladophora crispata (Roth) Kuetz.	D	D	—	—	—	—	—	—	—	—	—
Closterium aciculare T. West	C	C	Oct, Dec	Mar, Apr, Jun, Sep, Oct	—	1	L	L	(I)	(i)	I
C. acutum (Lyngb.) de Bréb.	C	C	Aug, Oct	Nov	—	1	L	L	(I)	I+	I
C. parvulum Naeg.	R	C	—	Jul, Sep	—	—	—	—	—	d+	—

C. sp. 1	R	R	—	—	—	—	—	—	—	—	—
C. sp. 3	—	R	—	—	—	—	—	—	—	—	—
Cosmarium sp.	C	R	May	—	—	—	—	—	(I)	—	—
Crucigenia rectangularis (Braun) Gay	C	R	Feb	—	—	—	F	—	(i)	—	—
Cyclotella meneghiniana Kuetz.	C	C	Feb, Dec	Feb, Aug, Oct, Nov	—	1	F	F	(I)	D+	X
Diacanthos belenophorus Korch.	R	—	—	—	—	—	—	—	—	—	—
Diatoms (undetermined species)	C	C	Aug, Sep, Nov	Jan	1	1	F	F	d+	D+	D
Dictyosphaerium pulchellum Wood	—	R	—	—	—	—	—	—	—	—	—
Dinobryon sertularia Ehrenb.	C	—	Oct, Dec	—	2	—	F	—	(I)	—	—
Eudorina elegans Ehrenb.	R	R	—	—	—	—	—	—	—	—	—
Euglena acus Ehrenb.	—	R	—	—	—	—	—	—	—	—	—
E. polymorpha Dang.	C	C	May–Jul, Feb, Oct	Jan–Mar, Jun	1	1	F	F	d+	D+	D
E. aff. *tripteris* (Dujardin) Klebs	—	R	—	—	—	—	—	—	—	—	—
E. sp. 1	R	—	—	—	—	—	—	—	—	—	—
E. sp. 2	C	C	Jan, Aug	Dec	—	1	F	F	i+	i+	—
E. sp. 3	C	—	Jun, Aug	—	—	—	—	—	—	—	—
Glenodinium sp.	R	—	—	—	—	—	—	—	—	—	—
Golenkinia sp.	R	—	—	—	—	—	—	—	—	—	—
Gonium pectorale Muell.	R	R	—	—	—	—	—	—	—	—	—
Hydrodictyon reticulatum (L.) Lag.	R	R	—	—	—	—	—	—	—	—	—
Lepocinclis sp.	R	—	—	—	—	—	—	—	—	—	—
Melosira granulata (Ehrenb.) Ralfs	C	C	Jan	Nov–Jun	2	2	—	F	I+	(I)	I
M. variana Ag.	C	C	May, Oct	Feb	—	—	F	F	d+	D+	D
Micractinium pusillum Fres.	—	R	—	—	—	—	—	—	—	—	—
Microcoleus lyngbyaceus (Kuetz.) Crouan	C	C	Apr	Feb	—	—	—	F	(i)	I+	I
Mougeota sp.	—	D	—	—	—	—	—	—	—	—	—
Nephrocytium agardianum Naeg.	C	C	Jul, Aug, Oct, Nov	Feb	1	—	—	—	(I)	(I)	I
Nodularia sp.	R	—	—	—	—	—	—	—	—	—	—
Oedogonium sp.	D	—	—	—	—	—	—	—	—	—	—
Oocystis gigas Archer	C	C	Mar, Apr, Aug	Nov	1	1	L	L	I+	D+	X

Taxon	1 Frequency		2 Seasonal effect		3 Abundance		4 Behaviour		5 Effect of drought		
Dam:	LO	GL	LO	GL	LO	GL	LO	GL	LO	GL	Comp.
O. parva West & West	C	C	Apr, Sep	Oct	—	—	L	L	I+	(I)	I
Oscillatoria ? lutea Ag.	C	C	Apr, Jun, Oct	Mar–May	—	—	—	F	D+	D+	D
Pandorina morum (Muell.) Bory	C	C	Dec	Jan	—	—	F	F	d+	(D)	D
Pediastrum boryanum (Turp.) Meneghini	R	R	—	—	—	—	—	—	—	—	—
P. duplex Meyen	C	C	Dec	Jan, Jul	—	—	F	F	(I)	(I)	I
Peridinium granulosum P'fair	C	C	Mar	Jan, Feb, Apr	1	1	L	L	(I)	(I)	I
Phacus caudatus Huebner	R	R	—	—	—	—	—	—	—	—	—
P. sp.	R	—	—	—	—	—	—	—	—	—	—
Pleurotaenium sp.	R	—	—	—	—	—	—	—	—	—	—
Scenedesmus abundans (Kirchner) Chodat	—	R	—	—	—	—	—	—	—	—	—
S. bijugus (Turp.) Kuetz.	C	C	Oct	Jan	—	—	—	—	(I)	(I)	I
S. obliquus (Turp.) Kuetz.	R	R	—	—	—	—	—	—	—	—	—
S. quadricaudus (Turp.) de Bréb.	R	C	—	Jan	—	—	—	F	—	—	—
Schizothrix calcicola (Ag.) Gomont	C	C	Dec	Jan	—	—	L	F	D+	D+	D
Schroederia judayi G. M. Smith	C	C	Apr–Jun, Aug	Dec	—	—	—	—	I+	See Text	
Sphaerocystis schroeteri Chodat	C	C	Dec	Jan	2	2	—	F	I+	See Text	
Spirogyra sp.	D	D	—	—	—	—	—	—	—	—	—
Spirulina subsalsa Oersted	R	—	—	—	—	—	—	—	—	—	—
Staurastrum pingue Teiling	C	C	Sep	Jun	2	1	—	L	I+	(I)	I
Stigeoclonium sp.	D	—	—	—	—	—	—	—	—	—	—
Synura adamsii G. M. Smith	C	R	Jul	—	1	—	F	—	D+	—	—
Tetraëdron hastatum (Reinsch.) Hansgirg	R	—	—	—	—	—	—	—	—	—	—

T. minimum (A. Braun) Hansgirg	—	R	—	—	—	—	—	—	—	—	—
T. trigonum (Naeg.) Hansgirg	R	—	—	—	—	—	—	—	—	—	—
Tetraspora lubrica (Roth) Ag.	R	R	—	—	—	—	—	—	—	—	—
Trachelomonas armata (Ehrenb.) Stein	C	C	Jan, Feb	Apr, Jul, Nov–Jan	1	—	F	L	(I)	I+	I
T. girardiana (P'fair) Deflandre	R	R	—	—	—	—	—	—	—	—	—
Trachelomonas hispida (Perty) Stein	C	C	Jan, Mar, Jun, Sep	Jun, Aug, Oct–Jan	1	1	L	—	(I)	(i)	I
T. sp.	R	—	—	—	—	—	—	—	—	—	—
Ulothrix sp.	D	—	—	—	—	—	—	—	—	—	—
Volvox globator L.	C	C	Mar, Oct	Sep	1	1	F	F	(D)	(D)	D
Zygnema sp.	—	D	—	—	—	—	—	—	—	—	—

1. Frequency (all species). C = common species (>5%). R = rare species (≤5%). D = drift species.

2. Seasonal Effect (common species). Showing months of occurrence at most stations.

3. Abundance (common species). 1 = medium abundance rating. 2 = high abundance rating.

4. Behaviour (common species). F = Fluvial (more common at upstream stations). L = Lacustrine (more common at downstream locations).

5. Effect of Drought (common species). A frequency change of over 5% is considered significant and is shown by a capital letter; lesser changes are shown in lower case. I = Frequency increased with drought or remained high during drought. (I) = Increase in frequency occurred only or mainly in year of drought. I+ = Increased frequency continued or became greater in year following drought. D = Frequency decreased with drought. (D) = Decrease in frequency occurred only or mainly in year of drought. D+ = Decreased frequency continued or became lower in year following drought.
   Comp. — Comparison between the response of species common to Glenbawn and Lostock Dams. I = Increase common to both dams. D = Decrease common to both dams. X = Responses of species differ between dams. A common result is accepted when the figures for one or both dams reach significance and the trend is the same in both dams.

Table 2: Number of common lacustrine and fluvial species found in four dams. (Figures from present paper, May & Powell 1986 and May 1988).

	Chaffey Carcoar Lostock Glenbawn	Carcoar Lostock Glenbawn	Chaffey Lostock Glenbawn	Chaffey Carcoar Glenbawn	Lostock Glenbawn
Lacustrine	3	6	4	4	8
Fluvial	0	1	2	0	9

Drift and rare species were found more often in mid- and upstream stations of both Lostock and Glenbawn Dams, but there were fewer occurrences of medium or high abundance ratings in other species and fewer taxa exhibiting this behaviour in the upstream stations.

Depth

Both dams showed greater frequency of occurrence and of abundance of most taxa at most times in surface water, as was found at Chaffey and Carcoar Dams (May & Powell, 1986; May, 1988). Only *Melosira granulata* showed greater frequency of occurrence (in both dams) and of abundance (in Glenbawn) in bottom collections. Bowen & Small (1980) describe *Melosira granulata* blooming after circulation of filaments from the hypolimnion.

In contrast with the importance of algae in top water, Wiederholm (1973) found bottom fauna provided indicator organisms of ecological significance.

Drought and position of station

Of the eight common lacustrine species found in both Lostock and Glenbawn, six increased in frequency with drought; of the nine common fluvial species found in both dams, five decreased in frequency with drought, while only one increased (Table 1, Effect of Position of Station and of Drought). This indicates that fluvial taxa are, in general, more adversely affected by drought. The four taxa that responded differently to drought in the two dams are probably affected more by some other, as yet undetermined, factor.

Physicochemical results

From surface water data obtained from Glenbawn Dam by the Water Resources Commission, it can be shown that turbidity, ammonia and iron, and possibly total phosphorus, increased with both position upstream and drought, while carbonate decreased correspondingly. Nitrate increased with prolonged drought (in both surface and bottom water), but not with progress upstream.

It has been shown above that the fluvial taxa tend to be more adversely affected by drought than do lacustrine taxa. Thus, with an apparently adequate annual nutrient supply, those physicochemical factors which act in the same way with both position in dam and drought do not determine which taxa thrive at each place. However, as nitrate increased with prolonged drought but not with position of station, it seems likely that this could be important in determining the changes in distribution of some taxa with prolonged drought.

At Glenbawn Dam, during the drought times *Anacystis* gradually replaced *Anabaina* as the toxic alga of greater occurrence and abundance. Since this time interval is associated with increasing nitrate content this observation supports the results reported from Carcoar Dam (May, 1988) showing that the concentration of oxidised nitrogen determines which of these blue-green algal species is likely to occur in quantity.

Acknowledgements

These studies were carried out as part of the continuing study of water quality in New South Wales storages being undertaken by the Water Resources Commission of New South Wales, to whom I am grateful for collecting the water samples and for other assistance. I would also like to thank Mr. Andrew Mitchell for welcome editorial assistance.

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Appendix 1
Species recorded from Lostock (marked L) and Glenbawn Dams (marked G)

LG	*Actinastrum hantzschii* Lag.
L	*Agmenellum thermale* (Kuetz.) Drouet & Daily
LG	*Anabaina circinalis* Rabenh.
LG	*Anacystis cyanea* (Kuetz.) Drouet & Daily (= *Microcystis aeruginosa* Kuetz.)
LG	*Ankistrodesmus falcatus* (Corda) Ralfs
LG	*Aphanizomenon* (ecophene of *Calothrix parietina* (Naeg.) Thuret)
L	*Asterionella* sp.
LG	*Botryococcus braunii* Kuetz.
LG	*Ceratium hirundinella* (O.F. Muell.) Dujardin
G	*Chlamydomonas* sp.
L	*Chodatella chodati* (Bern.) Ley.
LG	*C. subsalsa* Lemm. (*Lagerheimia*)
LG	*Cladophora crispata* (Roth) Kuetz.
LG	*Closterium aciculare* T. West
LG	*C. acutum* (Lyngh.) de Bréb.
LG	*C. parvulum* Naeg.
LG	*C.* sp. 1
G	*C.* sp. 3
LG	*Cosmarium* sp.
LG	*Crucigenia rectangularis* (Braun) Gay.
LG	*Cyclotella meneghiniana* Kuetz.

L	*Diacanthos belenophorus* Korch.
LG	Diatoms (undetermined species)
G	*Dictyosphaerium pulchellum* Wood
L	*Dinobryon sertularia* Ehrenb.
LG	*Eudorina elegans* Ehrenb.
G	*Euglena acus* Ehrenb.
LG	*E. polymorpha* Dang.
G	*E.* aff. *tripteris* (Dujardin) Klebs
L	*E.* sp. 1
LG	*E.* sp. 2
L	*E.* sp. 3
L	*Glenodinium* sp.
L	*Golenkinia* sp.
LG	*Gonium pectorale* Muell.
LG	*Hydrodictyon reticulatum* (L.) Lag.
L	*Lepocinclis* sp.
LG	*Melosira granulata* (Ehrenb.) Ralfs
LG	*M. varians* Ag.
G	*Micractinium pusillum* Fres.
LG	*Microcoleus lyngbyaceus* (Kuetz.) Crouan
G	*Mougeota* sp.
LG	*Nephrocytium agardianum* Naeg.
L	*Nodularia* sp.
L	*Oedogonium* sp.
LG	*Oocystis gigas* Archer
LG	*O. parva* West & West
LG	*Oscillatoria ? lutea* Ag.
LG	*Pandorina morum* (Muell.) Bory
LG	*Pediastrum boryanum* (Turp.) Meneghini
LG	*P. duplex* Meyen
LG	*Peridinium granulosum* P'fair
LG	*Phacus caudatus* Huebner
L	*P.* sp.
L	*Pleurotaenium* sp.
G	*Scenedesmus abundans* (Kirchner) Chodat
LG	*S. bijugus* (Turp.) Kuetz.
LG	*S. obliquus* (Turp.) Kuetz.
LG	*S. quadricaudus* (Turp.) de Bréb.
LG	*Schizothrix calcicola* (Ag.) Gomont
LG	*Schroederia judayi* G. M. Smith
LG	*Sphaerocystis schroeteri* Chodat
LG	*Spirogyra* sp.
L	*Spirulina subsalsa* Oersted
LG	*Staurastrum pingue* Teiling
L	*Stigeoclonium* sp.
LG	*Synura adamsii* G. M. Smith
L	*Tetraëdron hastatum* (Reinsch.) Hansgirg
G	*T. minimum* (A. Braun) Hansgirg
L	*T. trigonum* (Naeg.) Hansgirg
LG	*Tetraspora lubrica* (Roth) Ag.
LG	*Trachelomonas armata* (Ehrenb.) Stein
LG	*T. girardiana* (P'fair) Deflandre
LG	*Trachelomonas hispida* (Perty) Stein
L	*T.* sp.
L	*Ulothrix* sp.
LG	*Volvox globator* L.
G	*Zygnema* sp.

Understorey changes following fire at Myall Lakes, New South Wales

M.D. Fox

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Abstract

Fox, M.D. (National Herbarium of New South Wales, Royal Botanic Gardens, Australia 2000) 1988. Understorey changes following fire at Myall Lakes, New South Wales. Cunninghamia 2(1): 85-95. — Changes in understorey structure and composition of a series of 60 stands ranging in age from 1 month to 16 years since fire were examined at Myall Lakes National Park, New South Wales. Of the 122 vascular species encountered, 47% were obligate seedling regenerators while the remainder were vegetative regenerators. Height increased linearly with time and understorey cover re-established rapidly (due largely to *Pteridium esculentum* in the early years). Species richness was high immediately after fire, peaked at about 36 species after four years, dropped substantially at about ten years to climb to 39 species after 16 years. In contrast, plant species diversity peaked at about ten years and had dropped appreciably by 16 years.

Introduction

Fire is a conspicuous force in many Australian ecosystems and the literature on its effects on the biota is large (Gill, Groves & Noble 1981, and cited literature). However, there have been relatively few studies at the community level of the changes following fire. Classification of plant species by the mode of regeneration after fire has been used for at least 50 years, but few analyses of community composition using such classifications have been published.

This study was designed to analyse the response of a plant community to fire by considering the changes in composition of an open-forest understorey. The changes were assessed from the community attributes of species richness, diversity, and cover, as well as from a consideration of the mode of regeneration of the species. The study area was selected because it combined a relatively uniform substrate supporting a forest with different aged patches of regenerating understorey. Samples were taken in patches with different ages since fire. The same sampling technique has been used to monitor regeneration after sand-mining in the same forest (Fox & Fox 1984) and in nearby heathland (Fox & Fox 1978).

The study area

The forest grows on nutrient-poor Holocene sand near Seal Rocks (32°41′S, 152°09′E) in the Myall Lakes National Park, New South Wales. Seal Rocks is the northern limit of a triple embayment system bounded to the south by Hawkes Nest (Thom 1965). The sediment in the embayments is siliceous sand, the older Pleistocene horizon being heavily humate-impregnated and indurated, while the more recent Holocene deposits are in places lightly podzolized. In the Seal Rocks embayment the Holocene sand forms large transgressive sheets that have mantled the older surface. The northern and westward extent of this transgressive sheet is a high, long-walled ridge, Bridge Hill Ridge, which is in places over 100 m high.

The area experiences equable temperatures and some rain can be expected in every month (1352mm, 30 year annual average 1948–77, Sugarloaf Point 32°26′S, 152°32′E) with a peak in late autumn and early winter and moisture deficits through spring and summer.

The sand surface is forested with trees from 20 to 30 m tall having a basal area of about 25m^2 ha^{-1} and canopy cover of about 65% (Fox 1981). The main tree species are *Eucalyptus pilularis* Sm (MAIAA — code according to Pryor & Johnson 1971) and *Angophora costata* (Gaertn.) Druce (AAAD). The understorey is of scleromorphic shrubs, grasses, ferns and some herbs.

The forest is frequently burnt. For the 18 years preceding and encompassing this study, parts of the forest had burnt 15 times (Table 1). Some fires were both extensive and intense, burning several thousand hectares and incinerating the canopies of the eucalypts. However, many others were localized and of low intensity, burning only a few hundred hectares and possibly not even scorching the canopy. The latter kind were often the result of human activities in the area. It is likely that the 'natural' (pre-settlement) fire regime was of less frequent but more intense fires (Walker 1981). Myall Lakes falls within Walker's Fire Region 11, which has a fire interval of 5–15 years.

The fire season for this region is from mid-October to the end of January (Walker 1981). The more extensive fires in the past 18 years have been predominantly spring and summer fires (September 1980; October 1971, 1974, 1977, 1979, 1981; November 1968, 1980; January 1976, 1982; February 1975, 1979). There have also been winter fires (August 1974, 1980, 1984). The most severe (in extent and intensity) were the October 1968, January 1976 and August 1980 fires. The season of fires is important to the community regeneration in terms of the phenology of the individual species.

Table 1: The dates of 15 fires reported in the forest for the period November 1968 to August 1984. The numbers of sites and their ages at sampling (in brackets, years) for the four survey periods are shown.

Date of Fire		Date of Survey*			
		Sept.–Dec. 1976	**Nov. 1977**	**Feb. 1982**	**Mar. 1985**
November	1968	1 (8.0)	1 (9.0)	n.s.	3 (16.3)
October	1971	6 (5.0)	n.s.	n.s.	n.s.
August	1974	7 (2.2)	n.s.	n.s.	n.s.
October	1974	2 (1.9)	1 (3.1)	n.s.	2 (10.4)
February	1975	1 (1.5)	n.s.	n.s.	n.s.
January	1976	24 (0.8)	2 (1.8)	n.s.	n.s.
October	1977	—	n.s.	n.s.	1 (7.4)
February	1979	—	—	2 (3.0)	n.s.
October	1979	—	—	n.s.	n.s.
August	1980	—	—	n.s.	n.s.
September	1980	—	—	n.s.	n.s.
November	1980	—	—	3 (1.3)	1 (4.3)
October	1981	—	—	n.s.	n.s.
January	1982	—	—	2 (0.1)	n.s.
August	1984	—	—	—	1 (0.5)

* n.s. = not sampled

The effects of fire in this forest have been studied for litter accumulation (Fox, Fox & McKay 1979), and small mammal and vegetation regeneration (Fox & McKay 1981). The effects of fire frequency on the floristic composition and structure of woodland in the adjacent Eurunderee embayment (Fox & Fox 1986) have also been investigated.

Methods

In order to study the changes occurring as the community responds to the conditions after fire, a range of sites with different fire histories was used. Data were collected on four occasions spanning 8.5 years from a total of 60 sites, covering a range of ages since fire from one month to over 16 years. Table 1 lists the dates of the 15 fires recorded in the forest for a 16 year period and the number and ages of sites sampled. Because of the high frequency of fires in the forest, many samples were less than a year since fire (n = 27), eight were from one year to two years, 14 from two years to five years, six were between five and ten years, and five were more than ten years. The first set of 45 sites was strongly biased to sites less than a year old because of the extensive fire in January 1976. For this reason subsequent sampling concentrated on older sites of known age.

Figure 1 shows the location of the study sites, mostly south of the Seal Rocks road in an area of 2700 ha of open-forest. Initially 45 sites (numbered 1 to 45) were located on a 500 m grid and sampled in 1976 and 1977 (Fox 1981), with an additional seven sites (46 to 52) located on a transect from the high ridge to the sea (1982), while the 1985 sites (53 to 60) were largely selected to sample sites that had not then burnt for over ten years.

At sites 1 to 45 a quadrat of 0.04 ha (4 x 100 m) was used. The other 15 sites used a larger quadrat (20 x 100 m) to be consistent with data collected from a variety of other communities. All vascular plant species in the understorey (including small trees such as *Banksia serrata* and *Xylomelum pyriforme)* within each quadrat were recorded as the species richness for that site. The sixty sites were grouped into 12 age classes, segregating the smaller and larger quadrat sizes.

At each site the cover of understorey species was measured as line intercepts on a 100 m transect. The height of the understorey was measured at ten points along the transect and a mean value for the site calculated. Both height and cover measurements were independent of quadrat size and were grouped into ten age classes. Using cover values as measures of abundance, species diversity was calculated as the inverse of Simpson's (1949) index of concentration:

$$\Delta_3 = (\Sigma p_i^2)^{-1}$$

where p_i is the proportion of species i in the sample (Hurlbert 1971). Because diversity incorporates richness, the same twelve age classes were used as were distinguished for the richness data.

All vascular plant species occurring in the 60 sites were classified into one of the seven regeneration categories recognized by Gill (1975, 1981), based on observation in the field or consultation with colleagues. In some cases it was evident that some individuals of a species, otherwise considered to be an obligate seeder, may survive a low intensity fire and show vegetative growth from existing structures. Conversely examples of vegetative regenerators occasionally being killed by fire were also observed. All of the vegetative regenerators (categories IV, V, VI and VII) are also facultative seedling regenerators. In all such cases the usual (i.e. the population's) mode of regeneration after fire in the Seal Rocks open-forest was recorded for the species (see Appendix I). The seven regeneration categories (from Gill 1975) are:

I Mature plant killed by fire, seed stored on plant.
II Mature plant killed by fire, seed stored in soil.
III Mature plant killed by fire, seed storage absent.
IV Mature plant survives, sprouts from root suckers or horizontal rhizomes.
V Mature plant survives, sprouts from basal stem or vertical rhizome.
VI Mature plant survives, sprouts from aerial epicormic buds.
VII Mature plant survives, sprouts from undamaged buds that were active pre-fire.

Species fitting the first three categories are sometimes referred to as fire-sensitive species or as obligate seedling regenerators, the other four categories contain fire-resistant species, also referred to as vegetative regenerators or resprouters. At each site the percentage contributions to total richness of fire-sensitive species and fire-resistant species were calculated, and the percentage of total cover of each type also calculated.

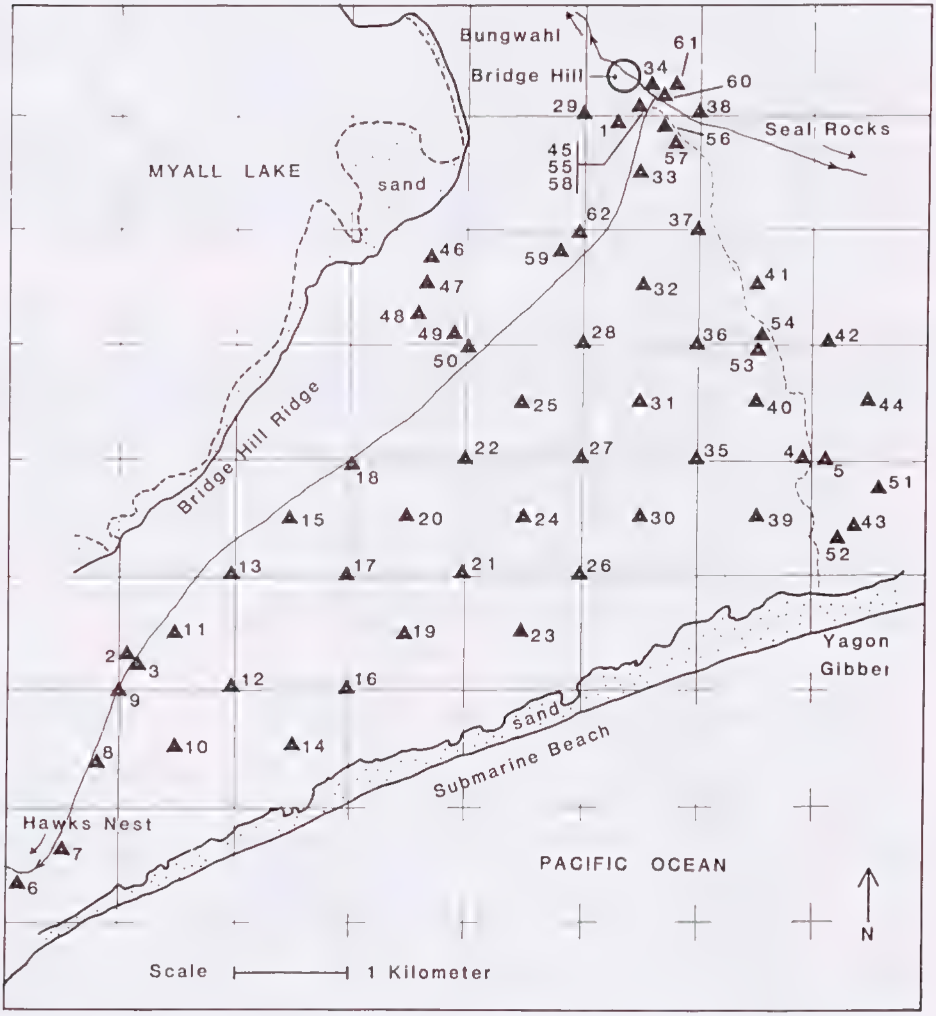

Figure 1. The location of the sixty sites covering approximately 2700ha of open-forest in Myall Lakes National Park.

Results

There is a statistically significant linear increase in the height of the understorey with time since fire (n = 60, r = 0.9764, $p < 0.001$). Figure 2 shows mean values for ten age classes with the regression line calculated from the 60 individual values. Sixteen years after fire the understorey was four metres tall.

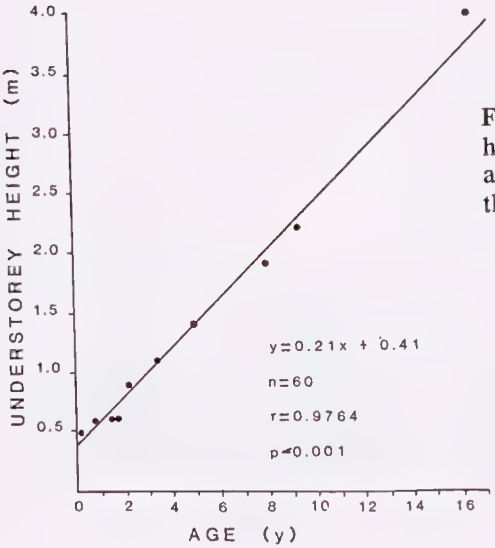

Figure 2. The linear increase in understorey height with time since fire. The points shown are the mean values for ten age classes; the line is the regression for the 60 sites.

One hundred and twenty two vascular plant species were encountered in the 60 sites (Appendix I). The average richness (+/− S.E.) of the sites was 34.8 +/− 0.7 [range 22–50]. There was no significant difference between the richness of the 0.04 ha plots ($\bar{x}$ = 34.7 +/− 0.8 species, n = 45) and the larger plots ($\bar{x}$ = 34.8 +/− 0.9 species, n = 15).

Figure 3 shows species richness as a function of time since fire. The mean number of species per site for 12 age classes is shown. There is a slight peak at four years, then a decline and then a rise to 39 species after 16 years. The data points can be fitted to a significant third order polynomial equation (r = 0.2665, 56 d.f., $p < 0.05 = 0.255$) which is the curve illustrated. Because of the high variability or 'noise' in the system, indicated by the magnitude of the standard error bars, only 7.1% of the variance is accounted for, but this is significantly better than a linear fit. This confirms that the drop in species richness at ten years and the second peak are real features. There are significantly more species after 16 years than immediately after fire (t = 3.84, d.f. = 4, $p < 0.02$).

Figure 4 shows the mean values for plant species diversity for the same age classes. These begin at values close to 3.0 but rise to peak at about 9.0 after ten years, and then drop substantially by 16 years after fire. The individual points demonstrate a significant fit to a quadratic equation (r = 0.648, $p < 0.005$) which explains 42% of the variance in plant species diversity and models the increase and subsequent decrease.

There is a significant negative correlation between species diversity and the amount of *Pteridium esculentum* cover (r = −0.7041, n = 60, $p < 0.001$).

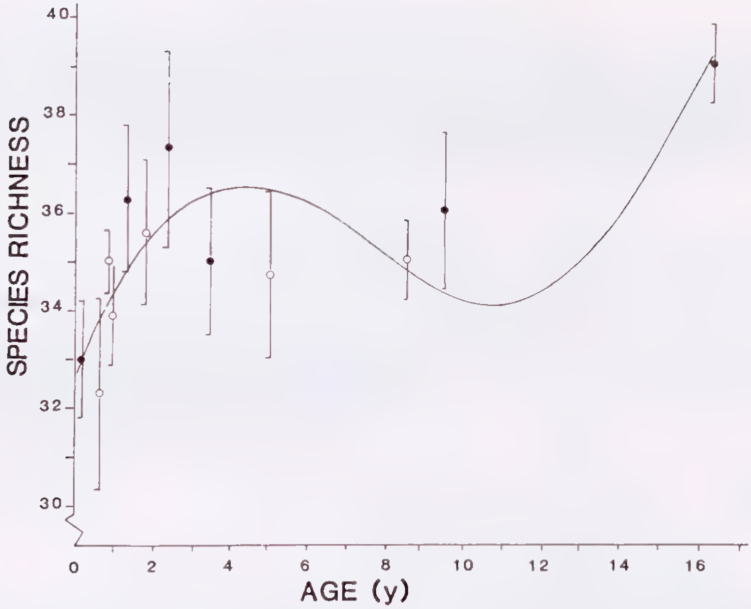

Figure 3. Changes in species richness with time since fire. The means (+/− standard error of the mean) for twelve age classes are shown. Open symbols are 0.04ha and closed symbols 0.2ha quadrats. The curve is a significant cubic function fitted to the 60 data points.

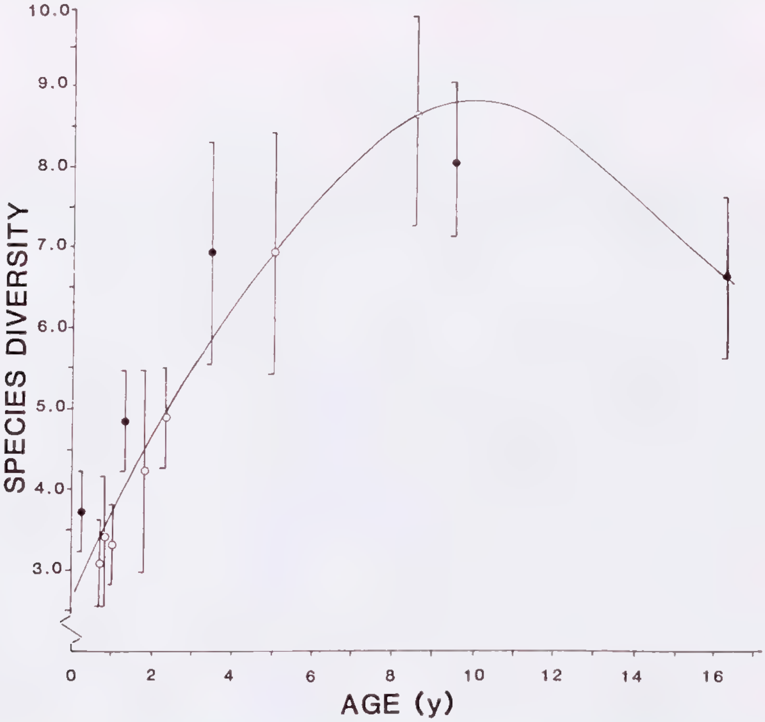

Figure 4. Changes in plant species diversity as a function of time since fire. The means (+/− standard error of the mean) for twelve age classes are shown. Open symbols are 0.04ha and closed symbols 0.2ha quadrats. The curve is a highly significant quadratic function fitted to the 60 data points.

Total understorey cover (Figure 5) returns to quite high values soon after fire, due largely to the rapid response of *Pteridium esculentum*. Cover tends to increase to peak values in the five to ten year period after fire and then to decline slightly. The greater part of the cover is contributed by the resprouting species. There is some fluctuation in the amount of cover from the vegetative regenerators, caused primarily by a second peak in *Pteridium* cover at five years.

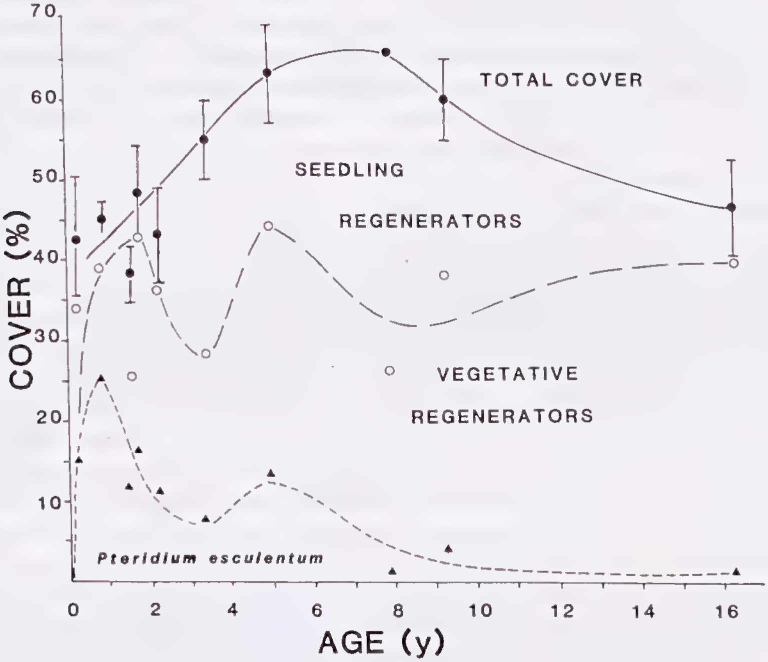

Figure 5. Changes in total cover partitioned into seedling and vegetative regenerators (with *Pteridium esculentum* shown separately) with time since fire. The same age classes are used as in Figures 2 and 3.

When the percentages of obligate seedling and vegetative regenerators are compared, these are remarkably constant with time since fire. The proportion of vegetative regenerators is approximately 61% from 0.3 years to 16.3 years. However, the percentage cover of these regeneration types fluctuates more widely. For the first five age classes (to 2.2 years) over 70% of total cover is provided by the resprouting species, this fluctuates widely between 40 and 80% for the next seven years and by 16 years returns to about 85%.

Only one species was classified as retaining seed on the plant (I, *Banksia integrifolia*), although elsewhere it resprouts from epicormic buds and seed is released when mature; and one as having no seed storage (III, *Senecio lautus*). Of the large number of species in category II (seed stored in soil), many retain some seed on the plant for some time, but ultimately it is shed. Of the vegetative regenerators, most belong to category V (sprouts from basal stem or vertical rhizome), with fewer in categories IV and VI, and only three species in category VII (sprouting from undamaged buds active pre-fire). Of the total of 122 species, 47% are in categories I, II and III (the obligate seedling regenerators) while 53% are in the vegetative categories (IV, V, VI and VII).

Discussion

The Myall Lakes area may have a natural fire interval of 5–15 years (Walker 1981), so the sites that are 16.3 years old are close to the maximum for coastal eucalypt forest. Fuel loads for Fire Region 11 vary from 0.35–2.00 kg m^{-2}; Fox *et al.* (1979) estimated the litter steady-state for the Seal Rocks forest is 1.67 kg m^{-2}. This is at the higher end of the fuel range which in turn would lead to higher fire frequency. This is supported by a recent study indicating that the period between fires in this area probably falls in the 6–12 year range (Fox & Fox 1986) and by the litter steady-state which is reached after about ten years (Fox *et al.* 1979). Anthropogenic fires have increased this natural frequency for much of the forest to about every four years; the much older sites are small relict patches.

For at least the preceding 16 years the oldest sites have experienced only one fire while the younger sites have been burnt several times. This may introduce a factor which differentiates the sites and confounds the previous assumption of homogeneity. In woodland in the adjacent Eurunderee embayment, an area that had burnt twice in 12 years had significantly more species, greater shrub density and greater cover than an adjacent area that had only burnt once (Fox & Fox 1986).

The changes in diversity related primarily to changes in dominance (as expressed by cover) of the understorey species. The early stages of the pyric cycle were dominated by the rapid regrowth of *Pteridium esculentum* but in time its cover was reduced (Figure 5). The greater evenness of other species in the range three to ten years produced high diversity values. By 16 years the understorey was dominated by a few tall shrub species and diversity was reduced. Bell & Koch (1980) found that in jarrah forests both species richness and diversity increased to a maximum at three to five years and then declined. Russell & Parsons (1978) found in heath at Wilsons Promontory that the number of species was reduced from 60 to 49 over 21 years.

Understorey cover was not significantly correlated with either species richness or diversity. After an early increase from 40% it levels out at about 65% between five and ten years, before dropping to about 45% after 16 years. Fox & McKay (1981) have described the changes in the vertical structure of the vegetation profile for this forest for the first eight years after fire.

The relative importance of species capable of vegetative regeneration in this forest is very similar to values reported for other open-forests (Christensen *et al.* 1981). The most striking feature of the data presented here, however, is the consistency of this proportion during the 16 years since fire. This signifies that, regardless of the number of species comprising the understorey or its stage of regeneration after fire, there is the same ratio of sprouters to non-sprouters. With individuals of 47% of the species in the understorey killed by fire, a fire frequency of less than the time needed for those species to flower and set seed, could result in those species being lost from the community.

Two abutting areas of woodland in the Eurunderee embayment (just south of the Seal Rocks forest) with different recent fire histories (Fox & Fox 1986) show an interesting pattern of relative abundance of vegetative regenerators. The area that had burnt only once in the past 12 years had a ratio of 63:37 for seedling regenerators to vegetative regenerators while for the area that had burnt twice in the same period the ratio was 39:61; the area with the higher recent fire frequency had more vegetative regenerators. The Seal Rocks forest (47:53) is about half-way between these two.

Conclusions

The understorey of the open-forest at Seal Rocks rapidly regenerates following fire. Because of the abundance of species capable of regenerating vegetatively, and of obligate seedling regenerators which germinate rapidly, the species richness is quite high one month after fire and shows an interesting pattern of change with time since fire. Contrary to the decline in richness reported in the literature for other communities, the richness after 16 years is higher than that of younger sites. Cover responds quickly as well, mainly due to the rapid vegetative response of *Pteridium esculentum*. Understorey height increases linearly with time since fire.

The proportion of species capable of vegetative regrowth (53%) is similar to values reported for other open-forests. Over all sites 61% of species were resprouters and this is so for over 16 years since fire.

Acknowledgments

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Appendix I

The vascular plant species encountered in the 60 sites. Nomenclature follows Jacobs & Pickard (1981). The mode of regeneration after fire is given (Gill 1975), and * indicates that the species is introduced.

PTERIDOPHYTES

DENNSTAEDTIACEAE
  Pteridium esculentum IV
DICKSONIACEAE
  Culcita dubia IV
SCHIZACEAE
  Schizaea bifida V
  S. dichotoma V

GYMNOSPERMS

CUPRESSACEAE
  Callitris macleayana II
ZAMIACEAE
  Macrozamia communis VII

ANGIOSPERMS — DICOTYLEDONS

APIACEAE
  Actinotus helianthi II
  Platysace ericoides II
  P. lanceolata II
  Trachymene incisa II
ARALIACEAE
  Astrotricha longifolia II
  Polyscias sambucifolia V
ASTERACEAE
  **Conyza canadensis* var. *canadensis* IV
  Senecio lautus III
BAUERACEAE
  Bauera rubioides V
BIGNONIACEAE
  Pandorea pandorana II
CAMPANULACEAE
  Wahlenbergia communis II
CASUARINACEAE
  Allocasuarina torulosa V
CHLOANTHACEAE
  Chloanthes stoechadis II
CONVOLVULACEAE
  Convolvulus erubescens II
DILLENIACEAE
  Hibbertia acicularis II
  H. fasciculata II
  H. linearis V
  H. scandens II
EPACRIDACEAE
  Brachyloma daphnoides V
  Leucopogon ericoides V
  L. lanceolatus V
  L. margarodes VI
  L. virgatus V
  Melichris procumbens V
  Monotoca elliptica V
  Styphelia viridis II
  Woollsia pungens V
EUPHORBIACEAE
  Breynia oblongifolia II
  Poranthera micorphylla II
  Ricinocarpos pinifolius V
FABACEAE — Faboideae
  Aotus ericoides V
  Bossiaea ensata V
  B. heterophylla II
  Desmodium rhytidophyllum II
  Dillwynia retorta II
  Gompholobium latifolium II
  G. virgatum II
  Hardenbergia violacea V
  Hovea linearis V
  Indigofera australis V
  Kennedia rubicunda II
  Oxylobium ilicifolium II
  Phyllota phylicoides II
  Platylobium formosum II
  **Trifolium* sp. II

FABACEAE — Mimosoideae
- *Acacia falcata* II
- *A. longifolia* II
- *A. maidenii* II
- *A. sophoreae* II
- *A. suaveolens* II
- *A. terminalis* II
- *A. ulicifolia* II

GOODENIACEAE
- *Goodenia paniculata* IV

HALORAGACEAE
- *Gonocarpus teucrioides* II

LAURACEAE
- *Cassytha glabella* II
- *Endiandra sieberi* VII

LOGANIACEAE
- *Mitrasacme polymorpha* II

MYRTACEAE
- *Angophora costata* VI
- *Calytrix tetragona* II
- *Eucalyptus gummifera* VI
- *E. microcorys* VI
- *E. pilularis* VI
- *E. robusta* VI
- *Leptospermum attenuatum* VI
- *L. flavescens* V
- *L. liversidgei* V
- *Melaleuca quinquenervia* II
- *M. squarrosa* II

OLACACEAE
- *Olax stricta* IV

PITTOSPORACEAE
- *Billardiera scandens* V

PROTEACEAE
- *Banksia integrifolia* I
- *B. serrata* VI
- *Conospermum taxifolium* II
- *Persoonia lanceolata* II
- *P. levis* VI
- *P. linearis* VI
- *Xylomelum pyriforme* VI

RUBIACEAE
- *Opercularia diphylla* II
- *Pomax umbellata* II

RUTACEAE
- *Boronia pinnata* II
- *Correa reflexa* II
- *Eriostemon australasius* II

SANTALACEAE
- *Choretrum candollei* IV
- *Leptomeria acida* IV

SAPINDACEAE
- *Dodonaea triquetra* II

SMILACACEAE
- *Smilax australis* V
- *S. glyciphylla* V

STERCULIACEAE
- *Lasiopetalum ferrugineum* II

THYMELIACEAE
- *Pimelea linifolia* II

TREMANDRACEAE
- *Tetratheca thymifolia* II

URTICACEAE
- *Pilea microphylla* II

VIOLACEAE
- *Hybanthus filiformis* II
- *Viola hederacea* II

ANGIOSPERMS — MONOCOTYLEDONS

ANTHERICACEAE (p.p. Liliaceae)
- *Tricoryne elatior* II

DIANELLACEAE (p.p. Liliaceae)
- *Dianella caerulea* IV

CYPERACEAE
- *Lepidosperma longitudinale* V
- *Schoenus ericetorum* IV

HAEMODORACEAE
- *Haemodorum planifolium* V

IRIDACEAE
- *Patersonia glabrata* V

LOMANDRACEAE
- *Lomandra longifolia* IV
- *L. filiformis* V

ORCHIDACEAE
- *Acianthus fornicatus* V
- *Caladenia carnea* V
- *Caleana major* V
- *Dipodium punctatum* V
- *Lyperanthus nigricans* V
- *L. suaveolens* V
- *Microtis uniflora* V
- *Pterostylis acuminata* V
- *Thelymitra nuda* V

RESTIONACEAE
- *Restio tetraphyllus* IV

POACEAE
- *Imperata cylindrica* IV
- *Themeda australis* IV

XANTHORRHOEACEAE
- *Xanthorrhoea australis* VII

The botany of old cemeteries

E. J. McBarron, D. H. Benson and M. D. Doherty

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Abstract

McBarron[1], E. J., Benson[2], D. H., and Doherty[3], M. D. ([1]125 Dumaresq Street, Campbelltown, Australia 2560; [2]National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000; [3]National Parks and Wildlife Service, P.O. Box 1967, Hurstville, Australia 2220) 1988. The botany of old cemeteries. Cunninghamia 2(1): 97–105. — The floristic composition, both native and exotic, of seventeen cemeteries in the Campbelltown area, south-west of Sydney, was examined. A total of 505 species was recorded, 193 native, 235 exotic–naturalized, 16 native–planted and 61 exotic–planted species. Some old cemeteries may be worthy of protection as small reserves because of the reasonably high proportion (here 21-59%) or rarity of native species recorded in them. The data indicate the need to judge each on its merits. Herbicides and excessive cleaning-up are major threats.

Introduction

In long-established rural areas, remnant herbaceous or groundlayer vegetation (if it exists at all) is often confined to service corridors, and semi-neglected sites such as old cemeteries. In adjacent rural lands, however, most of the native groundlayer species have been destroyed by a century of intensive cultivation or grazing. Leigh, Boden & Briggs (1984) attribute the extinction of 57% of the 'now extinct' Australian species to agricultural practices.

The flora of service corridors generally has a mixture of native species and 'roadside weeds' of exotic origin. Such areas may be regularly or intermittently managed, traditionally by burning, but now increasingly by herbicide spraying.

Old cemeteries may have a more varied flora than service corridors. There may be some remnants of the original native flora mixed with cultivated plants, including those deliberately planted either for their funerary symbolism or personal associations, others that have become naturalized, and weeds. Price (1979) recorded nearly 400 species for Sydney's Rookwood Cemetery and adjacent hospital and golfcourse grounds; Betteridge (1981) listed 122 species for Gore Hill Cemetery.

There is public interest in the historical significance of old cemeteries (for example see Gilbert 1980) but their plants have been generally overlooked. Yet these may be important in terms of conservation and horticulture. Loneragan (1975) used a cemetery at Gingin near Perth to study patterns in vegetation using 40 native species. The cemetery had been regularly mown and burnt, but evidently included a valuable natural remnant in an otherwise agricultural landscape. Rookwood Cemetery contains valuable pockets of remnant native vegetation and includes populations of the rare shrub, *Acacia pubescens* (Price, 1979). Such sites may also provide refuges for dependent fauna. Key (1978) indicates two grasshopper species now largely restricted to cemeteries in the Southern Tablelands because of the changes to the original grasslands. As sources of old-fashioned cultivar material, roses in particular, cemeteries and churchyards are important to horticulturists and collectors (Nottle, 1983). Recent cleaning at Rookwood endangered a number of old roses well known to specialist groups such as the Heritage Rose Society (Stephanie Murphy pers. comm.).

Our aim was to examine the potential conservation value of a number of old cemeteries in terms of their native and horticultural floras. The cemeteries chosen are south-west of Sydney, on the Cumberland Plain.

Methods

Plant species are listed from 17 cemeteries at Appin, Campbelltown, Liverpool, Camden, Narellan and Denham Court; all sites on the low-rainfall part of the Cumberland Plain, south-west of Sydney (Figure 1). These cemeteries are all on Wianamatta Shale soils that originally carried woodland of *Eucalyptus moluccana*, *E. tereticornis* and *E. crebra* with a grassy, predominantly *Themeda australis*, understorey. All the cemeteries are more than 60 years old, most over 120 years old and include some of the oldest in Australia (Table 1). Cemeteries chosen all had some native species, those with only mown grass were not included.

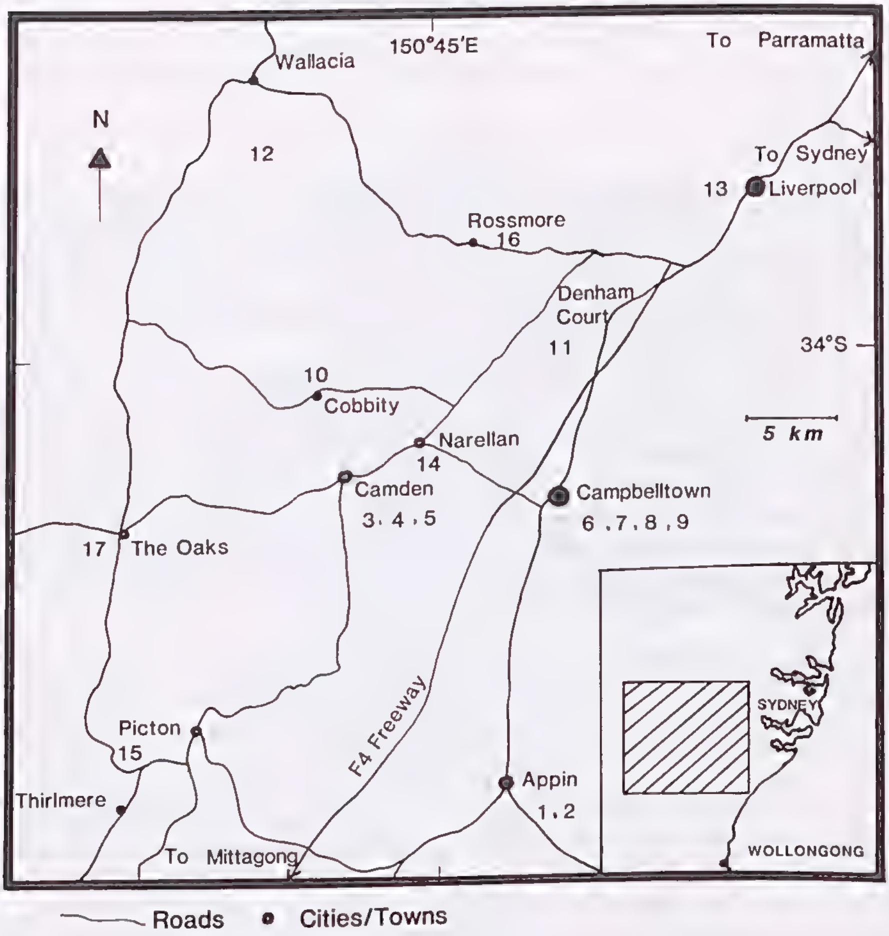

Figure 1. Location of cemeteries to the south-west of Sydney. Code numbers refer to Table 1.

Table 1: Code number, location, area and age of the 17 cemeteries examined

No.	Location	Approx. area (ha)	Oldest grave (year)
1.	Appin, St. Mark's Anglican Church	0.8	1842
2.	Appin, St. Bede's Roman Catholic Cemetery	0.6	1842
3.	Camden, General Cemetery	0.6	1924
4.	Camden, St. John's Anglican Church	1.6	1845
5.	Camden, St. Paul's Roman Catholic Cemetery, Cawdor Rd.	0.6	1843
6.	Campbelltown, Anglican Church of St. Peter	1.6	1823
7.	Campbelltown, St. John's Roman Catholic Cemetery	1.6	1827
8.	Campbelltown, Presbyterian Cemetery*	0.8	1848
9.	Campbelltown, Methodist Congregational Cemetery*	0.4	1865
10.	Cobbity, St. Paul's Anglican Church	0.8	1831
11.	Denham Court, Anglican Church of the Virgin Mary	1.2	1847
12.	Greendale, Old Roman Catholic Cemetery	0.6	1844
13.	Liverpool, General Cemetery†	2.0	—
14.	Narellan, St. Thomas' Anglican Church	0.8	1860
15.	Picton, General Cemetery	1.6	1840
16.	Rossmore, Anglican Church of the Holy Innocents	0.4	1846
17.	The Oaks, St. Matthew's Anglican Cemetery	0.6	1852

* Signifies a closed cemetery.

† Including that part of the old cemetery which was converted into the Pioneers Memorial Park in 1970–1974.

All species within the cemetery grounds were recorded, whether growing along paths, on graves, or in remnant natural vegetation. Cemetery bondaries were generally indicated by fences or clearly separated from other areas by mown lawns. Recordings were made in March, April and October 1984. Plant identifications were made by one of us (E.J.M.) and confirmed, where necessary, at the National Herbarium of New South Wales. Notes were made on the size, condition and management of the cemeteries.

Species were regarded as either native or exotic–naturalized if listed for the Central Coast Botanical Subdivision by Jacobs & Pickard (1981). Species not listed were regarded as planted, either as native–planted or exotic–planted. Five life-form classes: ferns, grasses, herbs and subshrubs, climbers and creepers, and shrubs and trees were used. The full species list is available form the Royal Botanic Gardens on request.

Results

The survey showed a rich flora with 505 species (Table 2). The number of species per cemetery ranged from 51 at Greendale (cemetery no. 12) to 164 at Liverpool (no. 13), with an average of 100 species per cemetery (Table 3).

Although only one species, the exotic herb *Plantago lanceolata* was recorded in all 17 cemeteries, 45 species were recorded from at least 50% of the cemeteries (9 or more) including 16 species from at least 75% of them (13 or more). The most frequent species were grasses and herbs.

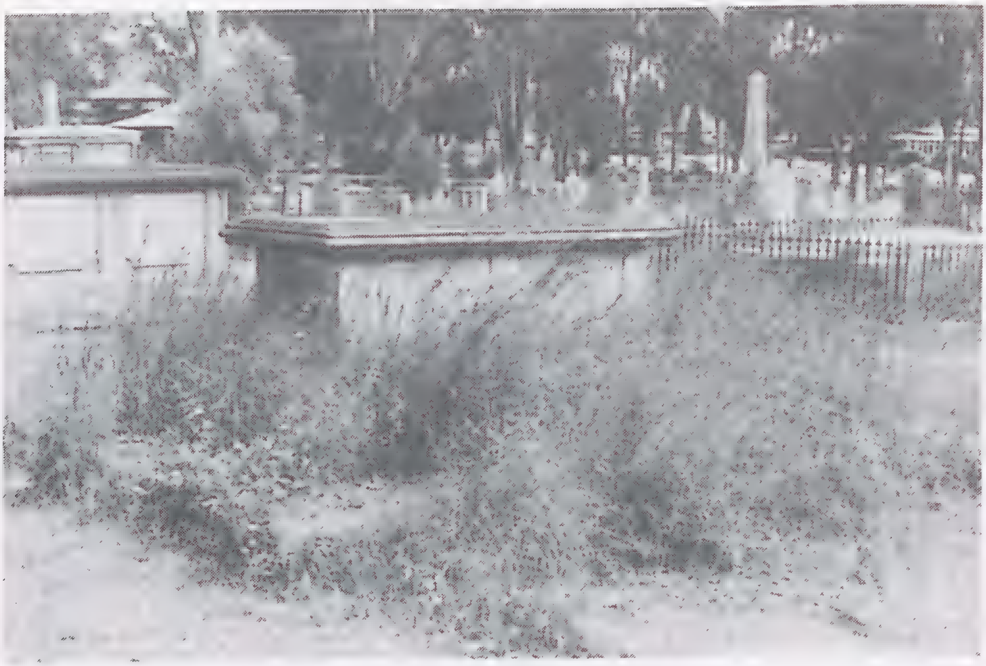

Figure 2. Grave with native *Themeda australis* and mixture of other species (Campbelltown — St Peter's Cemetery).

a) Native species

Of the flora, 193 (38%) were native species (Table 2). Of these 48% were herbs and subshrubs, 25% grasses and 20% shrubs. The number of native species per cemetery (Table 3) ranged from 17 at Cobbity Cemetery (no. 10) to 91 species at Liverpool (no. 13) (mean = 43, SD = 19). The native component made up between 21 and 59% of individual cemeteries (Table 3). The main native life-forms are herbs and subshrubs, from 8–47 species per cemetery, followed by grasses, 6–25 species per cemetery. Least important are ferns, 0–2 species per cemetery. The number of native species was not related to the size of the cemetery.

Native species either occurred in small bush remnants in undeveloped or little used parts of the cemetery, or along paths and on grave plots. Even when cemetery paths were mown, plants managed to survive in microhabitats such as the cracks in grave slabs, spaces between adjacent graves, along grave surrounds and edges, on fenced-off graves (often protected by iron surrounds), in the shade of headstones and under and around perimeter fences.

Liverpool (no. 13), with 91 native species (55% of the recorded species) had the most native species. It is largest in area and has had a fairly low intensity of usage and maintenance. Most of the native species are associated with old paths and fencelines as there are no distinct remnants of natural vegetation.

The lowest number of native species occurred in Cobbity Cemetery (no. 10), where only 17 species (22% of the recorded species) were native. This cemetery is carefully maintained, has no uncleared native vegetation and a high percentage of exotic–planted species. Most of the native species at Cobbity were growing on the grave plots themselves, rather than in untended parts of the cemetery.

Even in cemeteries with a low total number of species, native species may still comprise a very significant percentage. Greendale Cemetery (no. 12) had the

Table 2: Total numbers of species recorded by life-form and origin.

Origin	Life-form A	B	C	D	E	Total	Percentage
Native	4	49	92	9	39	193	38
Native-planted	0	0	1	0	15	16	3
Exotic	0	44	142	17	32	235	47
Exotic-planted	0	0	19	0	42	61	12
Total	4	93	254	26	128	505	
Percentage	1	18	50	5	26		100

(Life-forms: A = ferns, B = grasses, C = herbs and subshrubs, D = climbers and creepers, E= shrubs and trees.)

Table 3: Number and percentage of species recorded for the 17 cemeteries.

Cemetery	Native N %	Native-planted N %	Exotic-naturalized N %	Exotic-planted N %	Total
1.	41 (48)	0 (0)	39 (45)	6 (7)	86
2.	33 (50)	0 (0)	26 (39)	7 (11)	66
3.	35 (31)	3 (3)	69 (61)	7 (6)	114
4.	41 (30)	5 (4)	78 (57)	12 (9)	136
5.	30 (37)	0 (0)	50 (61)	2 (2)	82
6.	54 (36)	2 (2)	77 (52)	15 (10)	148
7.	48 (41)	4 (5)	57 (48)	9 (8)	118
8.	31 (31)	1 (2)	59 (59)	8 (8)	99
9.	24 (33)	0 (0)	41 (57)	7 (10)	72
10.	17 (21)	4 (5)	44 (55)	14 (19)	79
11.	45 (49)	1 (2)	39 (43)	6 (7)	91
12.	30 (59)	0 (0)	21 (41)	0 (0)	51
13.	91 (55)	3 (2)	64 (39)	6 (4)	164
14.	69 (55)	1 (1)	48 (39)	6 (5)	124
15.	33 (41)	1 (2)	40 (49)	7 (9)	81
16.	67 (49)	0 (0)	59 (43)	10 (8)	136
17.	34 (58)	6 (10)	16 (27)	3 (5)	59
Mean	43	2	49	7	100
SD	19	2	18	4	33

Cemeteries numbered as in Table 1.

lowest number of species (51) of any of the cemeteries, yet native species comprised 59% of these. This cemetery is unused and unmanaged.

Infrequent species and in particular those confined to one site made up about one-third of the native species and a similar proportion of the exotics (Table 4). Of the 74 native species found at only one site, 43% were found at Liverpool (no. 13) and 18% at Appin (no. 1). All except four cemeteries contained at least one infrequent native species.

Two native species coded as rare by Leigh, Briggs & Hartley (1981) were recorded. *Pimelea spicata*, coded 3RC (a rare species with a geographic range over 100km but not currently considered endangered or vulnerable), was found in a corner of the Narellan Cemetery. This is one of only three known surviving populations of this endemic Sydney species and a recoding of 3E (an endangered species with a range over 100km in serious risk of disappearing from the wild state within one or two decades if present land use and other causal factors continue to operate) has been recommended. *Acacia pubescens*, coded as 2E (an endangered species with a maximum geographic range of less than 100km), occurs as an uncommon plant at Liverpool Cemetery. The distribution of this species is similarly reduced. Leigh, Boden & Briggs (1984) state that land clearance for urban development poses a major threat to its continued survival in the wild. Another rare species, *Swainsona monticola*, was previously collected in St Paul's Roman Catholic Cemetery, Cawdor Rd, Camden (no. 5) by one of us (E.J.M.) in October 1965. The plants were destroyed during subsequent 'cleaning-up' and were absent in 1984. As this was the only known site in the Sydney area, the species is now locally extinct.

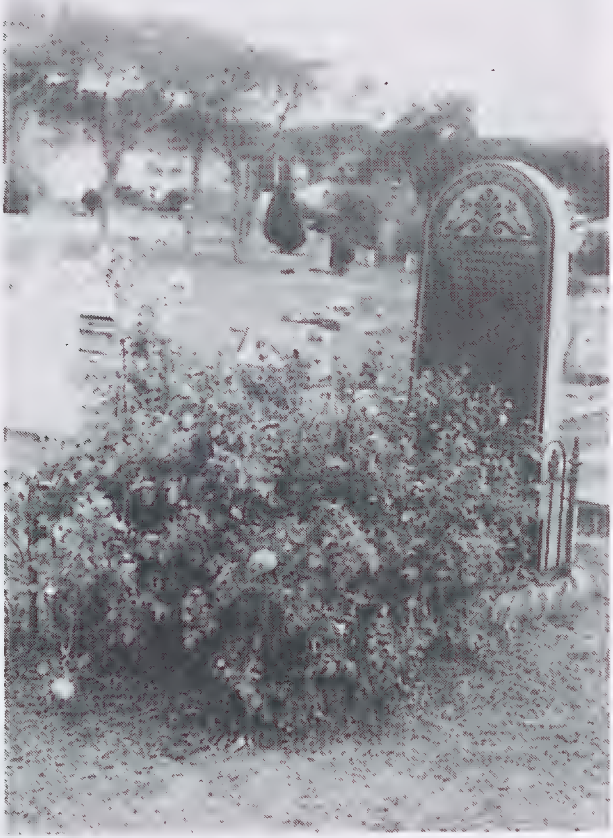

Figure 3. Grave with old rose cultivar (Picton General Cemetery).

b) Exotic–naturalized species

There were 235 exotic–naturalized species making up 47% of the total flora (Table 2). The mean number of exotic–naturalized species per cemetery ranged from 16 to 78 (mean = 49, SD = 18) (Table 3) which made up between 27% and 61% of the total number of species occurring in individual cemeteries. The main components of the exotic flora are herbs and sub-shrubs (C), 5–55 species per cemetery, followed by grasses (B), 7–21 species per cemetery. Exotic–naturalized species occupied similar microhabitats to native species.

Infrequent species, and in particular those confined to one site, made up about one-third of the exotics (Table 4). Infrequent exotic–naturalized species were found in all cemeteries (ranging from 1–12 per cemetery), but were much more evenly spread than native species.

Uncommon exotic species include *Oxalis bifurca* for which St Peter's Campbelltown (no. 6), is the only known locality in the Sydney Region (Beadle, Evans & Carolin, 1982). Species also occur which are naturalized locally but are not included in Beadle *et al.*, (1982), for example *Ornithogalum caudatum* at Rossmore (no. 16).

Table 4: Number of infrequent species* recorded for the 17 cemeteries.

Cemetery	Native	Exotic–naturalized	Native–planted and exotic–planted
1.	13	4	3
2.	6	5	3
3.	2	7	3
4.	2	10	4
5.	1	4	1
6.	1	8	4
7.	1	5	0
8.	0	2	2
9.	1	1	1
10.	1	8	5
11.	0	4	0
12.	0	3	0
13.	32	12	5
14.	9	5	1
15.	0	3	1
16.	2	5	3
17.	3	2	3

* Recorded at only one site.
Cemeteries numbered as in Table 1.

c) Native–planted

These are Australian native species that are not naturally found in the Campbelltown area. Only 16 native–planted species were recorded, 3% of the total species, and almost all were trees and shrubs. They were recorded at 11 of the 17 cemeteries. Tree species are mainly *Eucalyptus* and the shrubs mainly contemporary horticultural species. Two native species used in older plantings are *Araucaria bidwillii* and *Grevillea robusta.*

d) Exotic–planted

The exotic–planted species totalled 61 or 12% of the flora (Table 2). Two-thirds were trees and shrubs. They were found in almost all cemeteries (ranging from 0–15 species per cemetery) (Table 3). These include a number of exotic species, varieties and cultivars surviving from the Victorian era. Some were planted for their traditional associations, for example the Funereal Cypress, *Cupressus funebris* (Betteridge 1981). Other funereal plants recorded were *Pinus pinea* and the native *Araucaria bidwillii.*

The Victorian garden plants include a number of old rose species (*Rosa odorata*, *R. chinensis* var. *minima*) and unidentified cultivars. Some of the Victorian garden plantings reflect times before the potential for some of these hardy plants to become weeds elsewhere, particularly in bushland, was foreseen. *Oxalis* spp., *Vinca major* (Periwinkle) and *Lonicera japonica* (Honeysuckle), for instance, are now usually regarded as weeds.

Discussion

There is considerable conservation value in preserving different genotypes or variants of native species in areas where all other natural populations have disappeared, or are likely to be destroyed in the future. The network of small natural areas fulfils this role (National Trust of Australia–NSW 1984). Although not normally considered part of this network, old cemeteries may be important.

The evidence supports the case for considering some old cemeteries as having potential botanical and horticultural, as well as the normally accepted historical, conservation value. Old cemeteries may contain a surprising number of both native and exotic species, including a high proportion of 'infrequent' species. The latter include rare or locally restricted native species. Some cemeteries have higher proportions of infrequent species than others, but some may be found even in relatively tidy cemeteries. This study does not attempt to justify blanket protection of all old cemeteries, but contains data suggesting that each should be judged on its merits after survey.

The long-term conservation value (speaking in terms of centuries) of such areas is impossible to evaluate, although the older cemeteries have evidently maintained populations of species successfully for over a century. The loss of *Swainsona monticola* from one cemetery however, indicates their vulnerability to unsympathetic management. In particular herbicide spraying and excessive neatness should be avoided (see Appendix). Regrettably since the survey was completed several of the cemeteries have been sprayed or completely cleared.

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Appendix

Some recommended management procedures that will help maintain maximum species richness, particularly of native species, in a cemetery:
a) remnant stands of native vegetation should be retained
b) blanket use of herbicides should be avoided
c) the judicious use of fire is preferable to the use of chemical sprays
d) hand weeding and stump poisoning should be used to eradicate woody weeds such as lantana and privet
e) mowing should be confined to walkways and access areas
f) where native plants are a component of grassy areas, mowing should not take place until late spring (late November) in order to allow native lillies, grasses and terrestrial orchids to flower and set seed
g) mower blades should be raised a few centimetres off the ground so that the area is not cut back to bare earth
h) as there is often a concentration of native species along fencelines, a 1–2 metre wide uncleared strip should be left around fencelines where possible
i) grave plots should be left as undisturbed as possible
j) if disturbance to an area is inevitable due to expansion of the cemetery, the possibility of transplanting young plant specimens (or older specimens if there is no young material available) to an unused part of the cemetery should be investigated, especially if rare plants are involved
k) endangered plants should be left undisturbed, except for careful weeding to minimise competition and crowding.

The natural vegetation of the Katoomba 1:100 000 map sheet

D. A. Keith and D. H. Benson

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Abstract

Keith, D. A., & Benson, D. H. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1988. The natural vegetation of the Katoomba 1:100 000 map sheet. Cunninghamia* 2(1): 107–143. — The composition and extent of the present natural vegetation in the area covered by the Katoomba 1:100 000 map sheet 8930 (lat. 33°30′ – 34°00′S, long. 150°00′ – 150°30′E) is described and mapped from aerial photography and field traverses. The structure, characteristic species and associated environmental factors for 32 map units with 45 plant communities are described. These include small areas of rainforest and eucalypt tall open-forest, extensive tracts of open-forest and woodland, and patches of sclerophyllous heath and sedge-swamp.

Vegetation patterns are influenced by geology (mainly sedimentary and metasedimentary with limited igneous rocks), soil types (mainly low nutrient acid soils with variable texture), physiography (dissected sandstone plateaux and deep gorges), and by trends in elevation (ranging from 100 m to 1360 m above sea level) and rainfall (ranging from 750 mm to 1450 mm per annum).

Significant plant communities and rare species are listed. Plant communities needing conservation protection occur particularly in the Coxs River valley while rare localized species are concentrated in the wet habitats of the Upper Blue Mountains. Future management problems will relate to stream pollution and exotic weed invasion from increasing urban runoff, and changes in fire regimes near urban areas. There is a need for further botanical research into these problems.

Introduction

> 'Lofty, densely-timbered, mountainous ranges now appeared before us, peering over each other . . . their peculiar faces overhanging deep ravines as to seem to defy all further attempt to penetrate westerly.' Allan Cunningham (King's Botanist) 27th November 1823, quoted in Lee (1925).

Allan Cunningham's romantic vision from the slopes of Mt Tomah epitomises the outstanding elements of the Blue Mountains landscape: grand scenery and inaccessibility. His reference to 'lofty, densely-timbered, mountainous ranges', probably relating to forests on the basalt-capped peaks of the northern Blue Mountains, contrasts starkly with a later description of nearby sandstone vegetation — 'scanty and miserably stunted and gnarled timber' (Eccleston du Faur 1879). Such remarkable contrasts in vegetation occur within the area covered by the Katoomba 1:100 000 sheet.

The Katoomba 1:100 000 Vegetation Sheet (based on Katoomba 1:100 000 Topographic Sheet 8930, Division of National Mapping) is bounded by latitudes

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33°30′ – 34°00′S and longitudes 150°00′ – 150°30′E. It covers the Upper Blue Mountains, from Mt Wilson south to Lake Burragorang and the Coxs River, and west from Woodford to the Great Dividing Range. Elevation ranges from 100 to 1360 metres above sea level. This is the second sheet to be published in the Sydney Region Vegetation Map Series (See Figure 1).

Native vegetation in Blue Mountains National Park and Warragamba Catchment Area covers most of the map sheet. The main population centres are the chain of Blue Mountains towns along the Western Railway Line and Great Western Highway, including Woodford, Lawson, Wentwoth Falls, Leura, Katoomba, Blackheath and Mt Victoria. There are small rural settlements in the Coxs River valley.

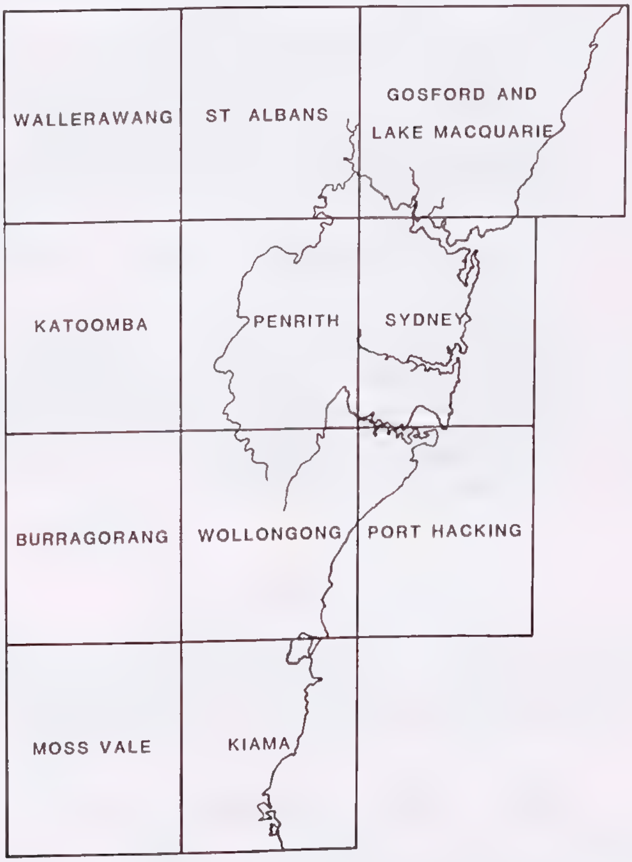

Figure 1. Key map for the 1:100 000 sheets in the Sydney Region Vegetation Map Series.

Climate

Average maximum temperatures relate strongly to altitude (Bureau of Meteorology 1979). Average January maxima are highest (28°C) around Lake Burragorang (150 m), decreasing to 23°C at Mt Victoria (1050 m) and 22°C at Jenolan State Forest (1150 m). Average minimum temperatures generally decrease from east to west. Average July minima range from 2 to 3°C at Wentworth Falls (900 m) to 0°C at Jenolan State Forest (1150 m). Temperatures as low as −3°C and −11°C have been recorded for Katoomba and Jenolan Caves respectively.

Winds from the west or northwest predominate all year round, though there are significant easterly and northeasterly winds during the summer months, November to April (data from Mt Victoria, Bureau of Meteorology 1979).

Rainfall patterns relate to elevation and distance from the coast (Bureau of Meteorology 1979). Average annual rainfall increases from 1100 mm near Woodford to 1400 mm at Leura and 1450 mm at Mt Tomah. There is a rainshadow effect in the Coxs River Valley, Little Hartley and Bowenfels receiving 750 mm and 780 mm respectively. Further west, at higher elevation, Jenolan State Forest receives 1150 mm annually. The driest months are generally July to September and the wettest are December to March, although the drier areas show little seasonality (Table 1).

Fogs occur frequently on the higher Blue Mountains, with Katoomba and Mt Victoria recording 55 and 90 fog days per year respectively. Frosts occur on 35 to 40 days of the year, mostly between April and November, half of these are regarded as 'severe' (Bureau of Meteorology 1979). Snow falls most frequently in July and August, Katoomba and Mt Victoria have an average of 3 and 10 snow days respectively per year.

Table 1: Average monthly rainfall (mm).

Station (altitude)	J	F	M	A	M	J	J	A	S	O	N	D	Total
Leura P.O. (975 m)	158	177	146	131	106	132	87	75	74	93	100	125	1401
Little Hartley (810 m)	79	73	69	59	55	66	62	53	45	55	59	73	748
Jenolan S.F. (1158 m)	113	115	99	81	86	117	80	93	71	96	93	105	1149

Geology and geomorphology

> 'These walls or cliffs rise . . . perpendicularly above the road, and their summits, broken and fissured in various fantastic forms, exactly resemble a ruined castle crowning the brow of the sheer precipice, with here and there a stunted tree or graceful shrub growing from crevices in the dark rock.' Louisa Ann Meredith at Hassans Walls (Meredith 1844).

The map sheet area lies on the western edge of the Sydney Basin. The Great Dividing Range traverses its northwestern edge and almost all of the area drains into the Hawkesbury–Nepean River System. Major watercouses include: Coxs River, flowing south then east into Lake Burragorang; Jenolan, Kanangra and Kowmung Rivers which drain the southwestern part of the area and join the Cox; the Kedumba River, flowing south into Lake Burragorang; and the Grose River which drains most of the Blue Mountains plateau and flows east to join the Nepean River. The highest parts of the area are in the southwest, with Mt Bindo (west of Hampton) reaching 1363 m and Ben Lomond (on the Boyd Plateau) reaching 1330 m.

The Blue Mountains, an extensive, dissected Triassic sandstone plateau, dominate the eastern half of the map sheet area. They rise from 500 to 600 m on the eastern edge of the map area to 1100 m near Mt Victoria, terminating in a spectacular north–south line of cliffs along the eastern side of the Hartley, Kanimbla and Megalong Valleys (Bembrick 1980). Hawkesbury Sandstone covers the eastern margin of the map area, with residual Wianamatta Shale capping the Bilpin Ridge and outcropping on Mt Tomah. Strata of the Narrabeen Group make up the main plateau. These consist of massive sandstone strata interbedded with narrow claystone bands, outcrops of which are associated with the formation of swamps in headwater valleys (Holland 1972).

Major peaks in the Blue Mountains, including Mt Wilson, Mt Haystack, Mt Tomah, Mt Bell, Mt Banks, Mt Caley and Mt Hay, are capped by remnants of Tertiary basalt. In a few places, most notably at Murphys Glen, diatremes or volcanic necks have intruded through the sandstone, though these are more common to the north and east of the map sheet area (Crawford *et al.* 1980).

At the base of the Triassic sandstone escarpment the Permian Illawarra Coal Measures are exposed. These incude shales, sandstones, conglomerates and chert with coal and torbanite seams (New South Wales Department of Mines 1966). The rapid weathering of these softer rocks undercuts the more resistant Triassic sandstones which collapse along joint lines to leave spectacular cliffs. While the Illawarra Coal Measures are mostly restricted to a narrow band below the clifflines, the Permian Shoalhaven Group, which underlies the coal measures, outcrops over larger areas beyond the escarpment as well as a number of residual cappings in the west of the area. Shoalhaven Group rocks include shales, conglomerates and sandstones. Both Permian rock types are exposed in the deeply entrenched Grose River gorge.

There is a large Carboniferous igneous intrusion, the Kanimbla Batholith, on much of the northwestern part of the map area, including the upper Coxs River valley and three outliers in the southwest. Uniform weathering of the adamellites, granites and granodiorites of this unit has given rise to the characteristically undulating 'granite country'. Smaller intrusions of gabbro and diorite are found in the western part of the map area (New South Wales Department of Mines 1966).

The Devonian Lambie Group underlies the Permian sediments, occupying a large area in the southwest of the map area. Smaller outcrops are exposed west of Lithgow, south of Hartley and in the Kedumba Valley. The quartzites, sandstones, siltstones and claystones of this group have been sculptured into very rugged country with mazes of deep gorges, steep slopes and narrow ridges. The Kanangra Gorge, for example, is up to 500 m deep.

The oldest rocks in the area are Devonian rhyolites and rhyo-dacites and Silurian tuff, limestones, siltstones, phyllites and slates which both outcrop in the Boyd Plateau–Jenolan Caves area (New South Wales Department of Mines 1966).

Soils

Soil types in the area covered by the Katoomba map sheet are described by Hamilton (1976). Soils derived from Triassic Sandstones in areas of high relief are grey-brown and yellow-brown uniform sands. Sandy yellow leached gradational soils (with ironstone gravel) are found on flatter parts of the plateau, paticularly from Katoomba to Mt Victoria. These 'sandstone soils' are rapidly permeable, very acid and very infertile.

Hardsetting loamy red and yellow texture-contrast soils (with ironstone gravel) are found on remnants of Wianamatta Shale on the Bilpin Ridge. These are moderately to slowly permeable, very acid and relatively infertile. Small areas of Tertiary basalt on the plateau have given rise to brown and red friable clay loams with moderate to slow permeability, slightly acid to neutral with high fertility.

Hardsetting yellow texture-contrast sandy loams occur on the Permian sandstone, shale and conglomerate deposits. These are moderately to slowly permeable, acid and relatively infertile.

Red-brown gradational sandy loams in the Coxs River valley are derived from Carboniferous granites. These soils are deep, rapidly permeable in their upper horizons, acid and have low to moderate fertility.

On the Devonian and Silurian substrates in the southwest of the map area are yellow leached gradational loams with moderate to slow permeability, acid with low fertility.

Land Use

Aborigines first occupied the Blue Mountains at least 14 000 years ago, and at various times three tribes may have used the area: the Gangangara people from the south; the Wiradjuri from the west; and the Daruks from the east (Robertson 1985).

Today much of the country still has natural vegetation and is protected within Blue Mountains National Park which covers most of the eastern half of the map area. Additional natural areas are found in Kanangra-Boyd National Park and Warragamba Catchment Area in the south, most of which is managed jointly by the National Parks and Wildlife Service and the Metropolitan Water, Sewerage and Drainage Board. A ribbon of tourist resorts and residential development has grown along the Main Western Railway.

Early European travellers found 'a wild and barren country' (Louisa Ann Meredith) though 'quite novel and extremely magnificent' (Charles Darwin). Less flattering was Barron Field, who at Blackheath saw hills, 'thrown together in a monotonous manner, and their clothing is very unpicturesque — a mere sea of harsh trees' (all quoted in Mackaness 1980). The spectacular landscapes of the Blue Mountains have inspired tourists from the mid-nineteenth century until the present.

There has been grazing in the Coxs River valley since the first road across the Blue Mountains was constructed in 1815. Orchards are a minor agricultural use on the Bilpin Ridge and Shipley Plateau.

Major forestry operations are associated with extensive pine plantations in Hampton and Jenolan State Forests. Native forests here, and on the Boyd Plateau (formerly Konangaroo State Forest), have been heavily logged, mainly for *Eucalyptus fastigata*.

Underground mining of the Illawarra Coal Measures is a major industry in the Bell–Lithgow area and there are small abandoned mines where the coal seams outcrop below the excarpment as far south as Mt Solitary. There are also major sand extraction sites on the plateau at Clarence.

The vegetation

(i) Methods

The vegetation has been classified into structural forms using the system proposed by Specht (1970). The structural forms are further subdivided into plant communities characterized by the dominant species. An alphanumeric code is used to identify individual map units. The numeric code represents the structural form of the plant community as determined from Specht (1970); (see Benson 1986) and the alphabetic code represents the characteristic species. The codes used are consistent throughout the Sydney region 1:100 000 vegetation map series, allowing the communities to be cross-referenced between maps. This system has been used in Queensland for the Moreton Region Vegetation Map Series (e.g. McDonald & Whiteman 1979).

Areas of vegetation with similar structural and floristic characteristics were grouped on the basis of aerial photopatterns, current geological mapping and limited field checking to form the map units. Black and white 1979/80 aerial photography by the New South Wales Department of Lands (approx. scale 1:40 000) was used. Only present day (that is, 1979/80) natural vegetation is mapped, though comments on the original vegetation of some cleared areas are provided. Compilation maps were prepared at 1:25 000 scale and subsequently reduced to 1:100 000 scale. Dyeline copies of the 1:25 000 compilation map sheets (Hartley, Mt Wilson, Hampton, Katoomba, Jenolan, Jamison, Kanangra and Bimlow) are available on request from the Royal Botanic Gardens, Sydney.

There are a number of constraints in reducing the complex pattern of natural vegetation to a map format. The map units recognized are not all of equivalent rank. This is because a number of them are essentially land units made up of several plant communities associated with a particular geological or physiographic type (e.g. map unit 10a), whereas others are more clearly plant associations (*sensu* Beadle & Costin 1952; e.g. map unit 26a). Generally the term 'plant community' is used for the basic vegetation unit. Where vegetation boundaries are relatively distinct, they are mapped with an unbroken line and where more diffuse, with a broken line. Communities have also been provided with common names based loosely on habitat and composition, for ease of reference.

Fieldwork was mostly conducted during the period 1983 to 1985. The descriptions of map units include notes on habitat, vegetation structure and the characteristic species of major strata. Reference has been made to any available descriptions or species lists.

Botanical names are those currently recognized at the National Herbarium of New South Wales. Recent nomenclatural changes include a revision of *Banksia* (George 1981), *Tristania* and allied genera (Wilson & Waterhouse 1982) and the separation of *Allocasuarina* from *Casuarina* (Johnson 1982).

General descriptions of the vegetation of Triassic sandstone areas were included in Pidgeon's (1937, 1938, 1940, 1941) vegetation study of the Central Coast of New South Wales. A broader view of vegetation patterns can be obtained from Beadle (1981). There have also been short studies done for environmental impact assessment work or university studies, copies of which are often very difficult to obtain. Dyson (1969), for example, surveyed the forests of the inner Warragamba Catchment, Black (1976, 1982) described and mapped the vegetation of the Boyd Plateau, while Duncan (1974) studied the vegetation of Kanangra Walls and Ti-Willa Plateau. An extensive species list for the map sheet area is being compiled by the National Herbarium and is available on request (for other lists see Pickard 1972, Bryant & Benson 1981 and Keith 1988). More generalized accounts of the vegetation of the Blue Mountains include those of Armstrong (1981) and Morrison (1985).

A summary of the plant communities recognized here, their structural formation, main canopy species, altitudinal range and geological substrate are given in Table 2. The vegetation map sheet is located inside the back cover.

(ii) Descriptions of map units

The map unit numbering system applies to the complete vegetation map series. Missing numbers are those used for plant communities that are not found on the Katoomba sheet.

Map unit 6c 'Glen Forest'.

Tall open-forest: *Eucalyptus deanei–Syncarpia glomulifera.*

In the lower Blue Mountains there are a number of diatremes, small amphitheatre-shaped valleys formed from eroded volcanic necks of Jurassic age, described in detail by Carne (1908). Murphys Glen is the best example on the Katoomba 1:100 000 map sheet, though others occur on Kings and Bimlow Tablelands. The soils in diatremes are deep, moist, sandy loams, derived from the mixing of sandstone and basalt or breccia substrates. This results from ring-faulting and collapse of the sandstone wall-rocks into the volcanic intrusion and the subsequent deposition of sand eroded from the surrounding sandstone ridges (Crawford *et al.* 1980).

The vegetation is tall open-forest dominated by trees of *E. deanei* and *Syncarpia glomulifera* with some *Angophora costata* ssp. *costata*. The understorey has tall shrubs of *Notelaea longifolia, Acacia obtusifolia, Pultenaea flexilis, Hakea dactyloides* and *Polyscias sambucifolia.* Climbers and scramblers are common including *Smilax australis, Tylophora barbata, Eustrephus latifolius, Cissus hypoglauca, Hibbertia dentata, Clematis aristata* and *Comesperma volubile.* The ground cover is dominated by *Culcita dubia, Dianella caerulea, Lomandra longifolia* and *Pteridium esculentum.*

Map unit 6d 'Camden White Gum Forest'.

Tall open-forest: *Eucalyptus benthamii–E. deanei.*

This community is restricted to the sandy loams of the narrow alluvial plain of the lower Kedumba River. *Eucalyptus benthamii* and *E. deanei* are dominant with the occasional *Angophora floribunda.* The understorey includes large shrubs of *Acacia parramattensis, A. filicifolia* and *Leptospermum flavescens* with a ground cover of *Imperata cylindrica.* Smaller, unmapped areas of Community 6d include a regenerating stand on cleared land at Reedy Creek and a small stand at Hayes Crossing on Cedar Creek. Other stands along the lower Coxs River were inundated following the construction of Warragamba Dam.

Eucalyptus benthamii was also originally found along the Nepean River, but with much of the Nepean Plain now cleared for agriculture, the *E. benthamii* community is known there only from Bents Basin near Wallacia where it occurs with *E. elata* (Benson 1985). A scattering of trees persists along the banks of the Nepean River between Wallacia and Camden.

Map unit 6g 'Moist Basalt Cap Forest'.

Tall open-forest: *Eucalyptus viminalis–E. blaxlandii–E. fastigata.*

> 'Upon entering the forest, the traveller is struck with the change in the appearance of the timbers from the Eucalypti [*sic*] of the open country, the stupendous size and extra-ordinary windings of the climbers . . . and with the magnificence of the tree ferns.' Allan Cunningham quoted in Lee (1925).

The Tertiary basalt caps of Mt Wilson, Mt Tomah, Mt Bell, Mt Banks, Mt Caley and Mt Hay in the Blue Mountains weather to a fertile clay-loam soil. At elevations of 800 to 1000 m this supports a tall open-forest on the summits and slopes, and rainforest (map unit 8c) in the moist, sheltered gullies, particularly those associated with the larger basalt areas of Mt Wilson and Mt Tomah.

In the tall open-forest on Mt Wilson *E. viminalis* and *E. blaxlandii* predominate with some *E. cypellocarpa.* On the other smaller peaks *E. viminalis* is replaced by *E. fastigata*, while *E. oreades* frequently inhabits more rocky slopes on the edges of the basalt.

Table 2: Map unit, common name, structure, main canopy species, geology and habitat of plant communities in the area covered by the Katoomba 1:100 000 map sheet.

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
6c	'Glen Forest'				
	TALL OPEN-FOREST	*Eucalyptus deanei* *Syncarpia glomulifera*	Jurassic diatremes	<650 m	Amphitheatre-shaped gullies
6d	'Camden White Gum Forest'				
	TALL OPEN-FOREST	*E. benthamii* *E. deanei*	Recent alluvium	<150 m	Banks of Kedumba River
6g	'Moist Basalt Cap Forest'				
	TALL OPEN-FOREST	*E. viminalis* *E. blaxlandii* *E. fastigata*	Basalt caps	>800 m	Ridges and slopes of residual basalt
6h	'Escarpment Complex'				
	TALL OPEN-FOREST	*E. deanei* *E. cypellocarpa* *Syncarpia glomulifera*	Illawarra Coal Measures	120–850 m	Escarpment slopes
	OPEN-FOREST	*Angophora costata* *E. piperita* *E. punctata*	Shoalhaven Group	120–850 m	Undulating country below escarpment slopes
	CLOSED-FOREST	*Ceratopetalum apetalum* *Doryphora sassafras*	Illawarra Coal Measures	120–850 m	Sheltered gullies on escarpment slopes
8c	'Montane Rainforest'				
	CLOSED-FOREST	*Ceratopetalum apetalum* *Doryphora sassafras* *Quintinia sieberi*	Illawarra Coal Measures, Tertiary basalt	600–1000 m	Sheltered gullies on escarpment slopes. Also found on basalt caps
8d	'Kowmung Dry Rainforest'				
	CLOSED-FOREST	*Toona australis* *Ehretia acuminata* *Brachychiton populneum*	Devonian Lambie Group	300–700 m	Sheltered lower slopes in deeply dissected Kowmung area
9a	'Shale Cap Forest'				
	OPEN-FOREST	*Eucalyptus notabilis* *E. globoidea* *Syncarpia glomulifera*	Wianamatta Shale	<750 m	Ridgetop, Berambing to Bilpin
9i	'Blue Mountains Sandstone Plateau Forest'				
	OPEN-FOREST	*E. sieberi* *E. piperita*	Narrabeen Group	800–1150 m	Dissected sandstone plateaux
9j	'Montane Gully Forest'				
	OPEN-FOREST	*E. fastigata* *E. cypellocarpa* *E. dalrympleana*	Narrabeen Group	850–1100 m	Gorges and sheltered escarpment slopes
9m	'Megalong Forest'				
	OPEN-FOREST	*Angophora costata* *E. punctata* *E. sieberi*	Shoalhaven Group	400–750 m	Undulating country below escarpment slopes
9n	'Montane Moist Forest'				
	OPEN-FOREST	*E. fastigata* *E. dalrympleana* *E. viminalis*	Lambie Group, Carboniferous granites	>700 m	Steep slopes and moist sheltered gullies

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
9x	'River Oak Forest'				
	OPEN-FOREST	*Casuarina cunninghamiana*	Alluvium	<800 m	Along major watercourses
10ag	'Sydney Sandstone Complex'				
	OPEN-FOREST	*Angophora costata* *E. piperita* *E. agglomerata* *Syncarpia glomulifera*	Narrabeen Group, Hawkesbury Sandstone	<800 m	Dissected plateau in gullies
10ar	'Sydney Sandstone Complex'				
	WOODLAND	*E. gummifera* *E. sclerophylla* *E. oblonga*	Narrabeen Group, Hawkesbury Sandstone	<800 m	Dissected plateau on ridges
10h	'Tablelands Grassy Woodland Complex'				
	WOODLAND	*E. dives* *E. mannifera* *E. eugenioides*	Shoalhaven Group	>800 m	Undulating to hilly country
	WOODLAND	*E. pauciflora* *E. rubida*		>800 m	Valleys with frost hollows
	WOODLAND	*E. aggregata* *E. mannifera* *E. stellulata*		>800 m	Poorly drained depressions
10l	'Snow Gum Woodland'				
	WOODLAND	*E. pauciflora* *E. dalrympleana*	Lambie Group, Carboniferous granites	>1100 m	Undulating country on Great Dividing Range
	WOODLAND	*E. pauciflora* *E. rubida* *E. stellulata*		>1100 m	Poorly drained hollows
10m	'Mount Walker Complex'				
	WOODLAND	*E. macrorhyncha* *E. melliodora*	Devonian Lambie Group	>600 m	Rugged country around Mt Walker and south of Hartley
10o	'Yellow Box Woodland'				
	WOODLAND	*E. melliodora* *E. viminalis*	Carboniferous granites	250–850 m	Coxs River Valley
10p	'Kowmung Wilderness Complex'				
	WOODLAND	*E. tereticornis* *E. melliodora*	Devonian Lambie Group	<900 m	Dissected country of the lower Cox and Kowmung Rivers. Gullies and moist slopes
	WOODLAND	*E. fibrosa* *E. crebra* *E. eugenioides* *E. punctata*	Devonian Lambie Group	<900 m	Dissected country of the lower Cox and Kowmung Rivers. Ridges and drier aspects
10q	'Burragorang Ironbark Woodland'				
	WOODLAND	*E. crebra* *E. eugenioides* *E. punctata* *E. fibrosa*	Shoalhaven Group	<500 m	Undulating country

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
	WOODLAND	*E. sclerophylla* *Angophora bakeri*	Shoalhaven Group	<500 m	Western aspect of ridges in Kedumba Valley
10r	'Residual Sandstone Woodland'				
	WOODLAND	*E. sieberi* *E. blaxlandii*	Shoalhaven Group	>900 m	Rocky, high altitude ridges
10s	'Montane Woodland'				
	WOODLAND	*E. radiata* *E. dalrympleana*	Lambie Group, Carboniferous granites, Shoalhaven Group	>900 m	Gentle slopes, ridges & undulating country
	WOODLAND	*E. ovata* *E. stellulata*			Poorly drained depressions
10t	'Mount Blaxland Complex'				
	WOODLAND	*E. sieberi* *E. pulverulenta*	Devonian metamorphic & igneous rocks	700–1000 m	Mt Blaxland, Wentworths Sugarloaf
10u	'Jenolan Granite Woodland'				
	WOODLAND	*E. punctata* *E.* sp. nov. 'MAHEK' *E. sieberi*	Carboniferous granites	300–1100 m	Steep north-facing slopes
17a	'Black Range Scrub'				
	OPEN-SCRUB	*E. mannifera* *Leptospermum myrtifolium* *L.* sp. nov. 'A' *Patersonia fragilis*	Devonian Lambie Group	1050–1150 m	Soaks on southerly aspects of Black Range
20a	'Newnes Plateau Shrub Swamps'				
	CLOSED-HEATH	*Leptospermum lanigerum* *Baeckea linifolia* *Grevillea acanthifolia* *Xyris ustulata*	Narrabeen Group	>1000 m	Shrub-swamps in narrow headwater valleys
20b	'Coxs River Swamps'				
	CLOSED-HEATH	*Leptospermum obovatum* *L. juniperinum* *Grevillea acanthifolia*	Illawarra Coal Measures	>600 m	Valleys and headwaters of creeks
21c	'Montane Heath'				
	OPEN-HEATH	*E. stricta* *Allocasuarina nana* *Leptospermum attenuatum* *Phyllota squarrosa* *Eriostemon obovalis*	Narrabeen Group	>850 m	Exposed rocky ridges on shallow sandy soils, often on western aspects
	OPEN-HEATH	*Epacris reclinata* *Dracophyllum secundum* *Gleichenia rupestris*		>850 m	Moist rock faces
21d	'Pagoda Rock Complex'				
	OPEN-HEATH	*Allocasuarina nana* *Leptospermum arachnoides* *Lepidosperma viscidum*	Narrabeen Group	>750 m	Exposed sites on rock outcrops with shallow soils. Associated with extensive rocky platforms and 'Pagoda' rock formations

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
	OPEN-SCRUB	*Eucalyptus* sp. nov. 'MOKII'		>750 m	
	WOODLAND	*E. sieberi* *E. piperita*		>750 m	Small sheltered gullies between rocky knolls
21f	'Lower Blue Mountains Heath'				
	OPEN-HEATH	*E. stricta* *Allocasuarina nana* *Leptospermum attenuatum* *Phyllota phylicoides* *Eriostemon hispidulus*	Narrabeen sandstone	<850 m	Exposed rocky ridges on shallow sandy soils, often on western aspects
	OPEN-HEATH	*Epacris reclinata* *Dracophyllum secundum* *Gleichenia rupestris*		<850 m	Moist rock faces
26a	'Blue Mountains Sedge Swamps'				
	CLOSED-SEDGELAND	*Gymnoschoenus sphaerocephalus* *Lepidosperma limicola* *Xyris ustulata* *Baeckea linifolia*	Narrabeen sandstone with peaty sand	<1000 m	In headwater gullies or on hillsides
26b	'Boyd Plateau Bogs'				
	CLOSED-SEDGELAND	*Carex appressa* *C. gaudichaudiana* *Juncus holoschoenus* *Baeckea utilis*	Carboniferous granite with acid peats	>1200 m	In headwater gullies
	CLOSED-HEATH	*Leptospermum myrtifolium* *L. obovatum* *L. lanigerum*		>1200 m	In headwater gullies
C	Cleared	Native vegetation has been largely removed for agricultural, industrial or urban development but remnant vegetation of varying sizes and condition may remain.			

The understorey generally has scattered shrubs including *Acacia melanoxylon, A. penninervis, Polyscias sambucifolia, Astrotricha floccosa, Daviesia ulicifolia* and *Leucopogon lanceolatus* var. *lanceolatus*, and occasional tree ferns, *Cyathea australis*. There is a continuous ground cover of herbs such as *Libertia paniculata, Dianella laevis, Geranium solanderi* var. *solanderi, Viola betonicifolia, Centella asiatica* and *Stellaria pungens*, with ferns including *Blechnum cartilagineum, B. nudum, Doodia aspera* and *Pteridium esculentum*.

On the Boyd Plateau at Whalania Heights and south of Cunynghame Hill, basalt outcrops at much higher elevations (above 1200 m) but supports similar tall open-forest with *E. viminalis* and *E. fastigata*. Occasional shrubs in the understorey here include *Pultenaea altissima, Acacia dealbata, A. melanoxylon* and *Rubus parvifolius*, together with herbs such as *Geranium potentilloides* var. *abditum, Epilobium billardieranum* ssp. *cinereum, Acaena novae-zelandiae* and *Luzula flaccida*, and ferns including *Polystichum proliferum* and *Blechnum nudum*.

Ingram (1972) recounts the botanical history of Mt Tomah and provides a species list, while Brough, McLuckie & Petrie (1924), Petrie (1925) and McLuckie & Petrie (1926) give detailed descriptions of the vegetation of Mt Wilson.

Map unit 6h 'Escarpment Complex'.

Tall open-forest: *Eucalyptus deanei–E. cypellocarpa–Syncarpia glomulifera.*

Open-forest: *Angophora costata* ssp. *costata–E. piperita–E. punctata.*

Closed-forest: *Ceratopetalum apetalum–Doryphora sassafras.*

This map unit is a mosaic of three communities found on the moderate to steep slopes below the Triassic sandstone escarpments at low to moderate altitudes (120 to 850 m). The soils are relatively deep, moist but well-drained sandy loams with colluvial material from shales, sandstones and conglomerates of the Permian Illawarra Coal Measures and, to a lesser extent, the Shoalhaven Group.

The most widespread community in this unit is a tall open-forest dominated by *E. deanei, Syncarpia glomulifera, Angophora costata* ssp. *costata* and *Acacia elata. Eucalyptus cypellocarpa* replaces *E. deanei* at higher altitudes (above about 650 m), particularly along the slopes around Narrow Neck Peninsula (Figure 2). *Eucalyptus oreades* may be present on the upper slopes. There is a sparse small-tree stratum of *Callicoma serratifolia, Hakea salicifolia* and *Allocasuarina littoralis.* The understorey has a dense fern cover of *Culcita dubia, Pteridium esculentum* and *Blechnum cartilagineum,* with occasional emergent shrubs of *Platylobium formosum, Oxylobium ilicifolium, Bursaria longisepala, Leucopogon lanceolatus* var. *lanceolatus and Pultenaea scabra var. scabra.* Herbs and twiners include *Dianella caerulea, Clematis aristata, Smilax glyciphylla, Lomandra longifolia, Viola hederacea, Pratia purpurascens* and *Helichrysum scorpioides.* Blue Gum Forest in the Grose Valley is a good example of this community, though here *Eucalyptus deanei* occurs as a pure stand.

On the less sheltered, undulating terrain of the Kedumba and Grose Valleys, away from the escarpment, there is an open-forest community with *Angophora costata* ssp. *costata, E. piperita* ssp. *piperita, E. punctata, E. gummifera, E. oblonga* and *E. sieberi* in various combinations. This occurs on drier, more sandy soils on the sandstones and conglomerates of the Shoalhaven Group. While larger stands are mapped separately as 'Megalong Forest', small areas of this vegetation are associated with the 'Escarpment Complex'. Floristically this resembles the 'Sydney Sandstone Complex' vegetation on the Hawkesbury Sandstone (map units 10ag/10ar). The understorey is shrubby, 1 to 2 m tall and includes a diversity of proteaceous, myrtaceous and fabaceous shrubs such as *Banksia spinulosa* var. *spinulosa, B. serrata, Lambertia formosa, Persoonia linearis, Leptospermum attenuatum, Dillwynia retorta* and *Oxylobium ilicifolium.*

In moist, sheltered gullies running down the steep escarpment slopes (for example below Little Cedar Gap and below the Horseshoe Falls at Govetts Leap), a closed-forest community dominated by rainforest species, *Ceratopetalum apetalum, Acmena smithii* and *Doryphora sassafras* occurs. These narrow bands of rainforest are usually overtopped by eucalypt emergents, *E. deanei, E. cypellocarpa* or *E. oreades.* Small trees include *Backhousia myrtifolia, Tristaniopsis collina, Callicoma serratifolia, Elaeocarpus reticulatus, Pittosporum revolutum, Eupomatia laurina, Rapanea howittiana, Hedycarya angustifolia* and *Notelaea longifolia.* The understorey consists of occasional ferns such as *Blechnum cartilagineum, B. patersonii, Polystichum proliferum, Doodia aspera* and *Cyathea australis,* with vines of *Pandorea pandorana, Morinda jasminoides, Smilax australis, Eustrephus latifolius* and *Cissus hypoglauca* also present.

Map unit 8c 'Montane Rainforest'.

Closed-forest: *Ceratopetalum apetalum– Doryphora sassafras–Quintinia sieberi.*

Larger areas of Warm Temperate rainforest are found on sheltered southerly and south-easterly aspects of Mt Wilson and Mt Tomah and in the adjacent sandstone gullies with an elevational range from 600 to 1000 m. The soils here are

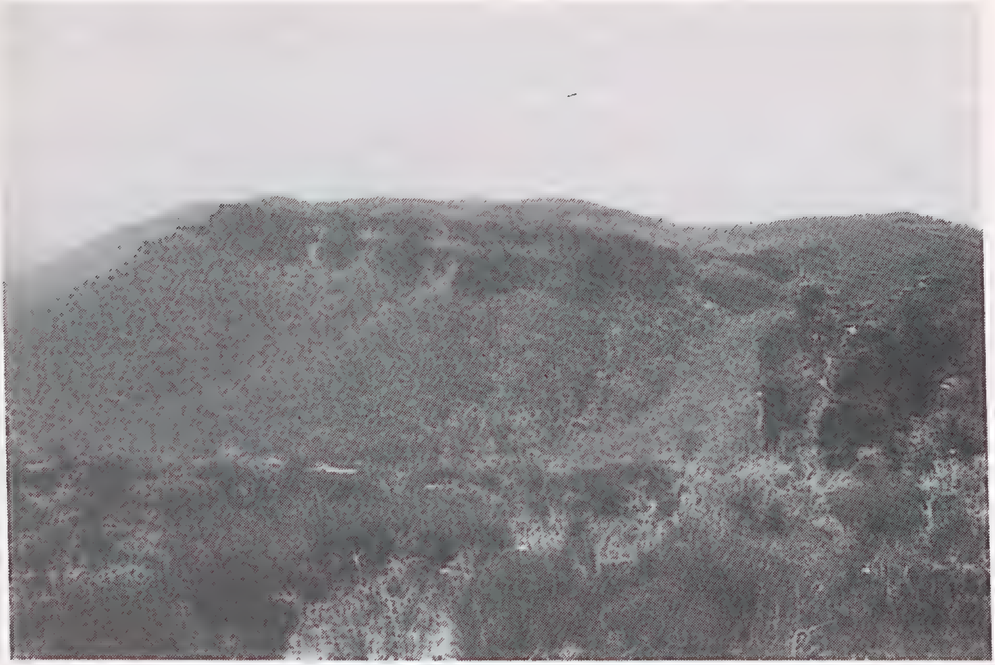

Figure 2. Looking north along the western escarpment of the Narrow Neck peninsula. Tall open-forest of *Eucalyptus cypellocarpa* dominates the slopes above Megalong Valley, with narrow bands of closed-forest in the heads of the gullies (map unit 6h). 'Montane Heath' (map unit 21c), foreground, predominates on the plateau surface.

deep, moist, fertile clay loams derived from the Tertiary basalt that caps these peaks. The adjacent sandstone gullies receive clay and nutrients in downwash from the basalt. More exposed areas of basalt support eucalypt tall open-forest (map unit 6g). Rainforest is also found in the sheltered gully of Pulpit Hill Creek, west of Blackheath, where the soils are enriched from shale bands of the Illawarra Coal Measures.

The dominant trees are *Ceratopetalum apetalum* and *Doryphora sassafras* with *Quintinia sieberi, Acmena smithii, Hedycarya angustifolia* and *Atherosperma moschatum*, the last two species indicating a Cool Temperate influence at the highest elevations. *Callicoma serratifolia* is abundant in the sandstone gullies but absent from the basalt (McLuckie & Petrie 1926).

The understorey also varies depending on the bedrock. The tree ferns, *Dicksonia antarctica* and *Cyathea australis* predominate on the basalt soil with a very sparse and patchy groundcover of herbs such as *Geranium solanderi* var. *solanderi* and *Centella asiatica* and smaller ferns including *Blechnum cartilagineum, Polystichum proliferum, Pellaea falcata* var. *falcata, Doodia aspera, Pteridium esculentum* and *Sticherus flabellatus*. There are also a number of climbers including *Pandorea pandorana, Tylophora barbata, Clematis aristata* and *Smilax australis*. In sandstone gullies the tree fern stratum is less important, allowing a more diverse understorey to develop. The shrubs *Polyscias sambucifolia, Elaeocarpus reticulatus, Lomatia myricoides* and *Prostanthera lasianthos* are more common. Detailed descriptions of this community at Mt Wilson are given by Brough, McLuckie & Petrie (1924), Petrie (1925), McLuckie & Petrie (1926) and Floyd (1984).

Less species-rich rainforests occur as narrow bands along creeks on the escarpment slopes. These are too small in area to be mapped at 1:100 000 scale and are included in the 'Escarpment complex' (unit 6h).

Map unit 8d 'Kowmung Dry Rainforest'.

Closed-forest: *Toona australis– Ehretia acuminata-Brachychiton populneum.*

Small patches of dry rainforest are found in the Kowmung wilderness, a deeply dissected, low-rainfall area of Devonian metamorphic rocks in the south-western part of the map sheet. The rainforest is restricted to small patches on the lower sheltered slopes of gorges between 300 and 700 m elevation. The largest stand occupies the south-facing slopes of Kanangra Gorge and resembles rainforest described by Floyd (1984) at Mt Colboyd further south. Numerous occurrences along the Kowmung River and its tributaries are too small to be mapped at 1:100 000 scale and are included within the 'Kowmung Wilderness Complex' (map unit 10p).

The major tree species are *Toona australis, Ehretia acuminata* and *Brachychiton populneum*, though a number of others are frequent. These include *Ficus rubiginosa, Dendrochnide excelsa, Alectryon subcinereus, Claoxylon australe* and *Backhousia myrtifolia*. The understorey contains shrubs of *Hymenanthera dentata, Rapanea howitteana, Notelaea longifolia, Trema aspera, Derringia amaranthoides, Pomaderis aspera* and *Seringia arborescens*. There are few vines, the main species being *Eustrephus latifolius, Aphanopetalum resinosum, Celastrus australis, Pandorea pandorana, Marsdenia flavescens and M. rostrata.* The sparse goundcover includes the ferns *Adiantum aethiopicum, Asplenium flabellifolium, Doodia aspera, Pteris tremula* and *Pellaea falcata*, herbs *Urtica incisa, Stellaria flaccida, Plectranthus parviflorus, Sigesbeckia orientalis, Hydrocotyle geraniifolia* and the grass, *Oplismenus aemulus.*

Adjacent dry slopes often support a 'blue bush' scrub with *Acacia binervia, A. falciformis* and the rare *A. clunies-rossii.*

Map unit 9a 'Shale Cap Forest'.

Open-forest: *Eucalyptus notabilis–E. globoidea– Syncarpia glomulifera.*

Along the Bilpin ridge are the most western remnants of the Wianamatta Shale cappings. Here, on the deep, relatively well-drained clay soils is an open-forest with *E. notabilis, E. globoidea* and *Syncarpia glomulifera. Eucalyptus piperita* ssp. *piperita* may be common where there is some sandstone influence. Wetter sites support *E. cypellocarpa* at the higher western end, while *E. deanei* and *E. punctata* occur further east. The understorey contains shrubs of *Acacia parramattensis, Indigofera australis, Hibbertia aspera* and *Helichrysum diosmifolium* with a moderately dense groundcover of the grasses *Entolasia marginata, Dichelachne rara, Echinopogon ovatus,* the herbs *Helichrysum elatum, Poranthera microphylla, Dichondra repens, Dianella caerulea,* and twiners including *Hardenbergia violacea, Kennedia rubicunda, Tylophora barbata* and *Eustrephus latifolius.* Because of their reasonably good agricultural soils, the natural vegetation of these shale cappings has been largely cleared for orchards and small farms.

Map unit 9i 'Blue Mountains Sandstone Plateau Forest'.

Open-forest: *Eucalyptus sieberi–E. piperita.*

Much of the Triassic sandstone plateau at higher altitudes (800 to 1150 m) is covered by an open-forest dominated by *E. sieberi* and *E. piperita* ssp. *piperita*. The soils are shallow, sandy, low in nutrients, well-drained and derived from Narrabeen Group sandstones. Taller variants of this community with *E. oreades, E. piperita* ssp. *piperita, E. sieberi* and *E. radiata* ssp. *radiata* occur in more sheltered situations, while *E. sieberi, E. sclerophylla, E. oblonga* and *E. mannifera* ssp.

gullickii dominate more exposed areas. The understorey is shrubby and includes such species as *Leptospermum attenuatum, Petrophile pulchella, Banksia ericifolia, B. spinulosa* var. *spinulosa, B. spinulosa* var. *cunninghamii, Persoonia chamaepitys* and *Acacia terminalis.*

The lower altitudinal limit of 800 m where this unit adjoins map unit 10a is concurrent with the margins of the higher elevation plateau and coincides with the distributional limits of a number of species. For example low altitude species such as *Angophora costata* ssp. *costata, E. gummifera, Syncarpia glomulifera, Acacia linifolia* and *Hibbertia empetrifolia* are common in map unit 10a but not in 9i, while higher altitude species such as *E. oreades, E. mannifera* ssp. *gullickii, E. radiata* ssp. *radiata, Banksia spinulosa* var. *cunninghamii, Persoonia chamaepitys, P. myrtilloides, Boronia microphylla* and *Stellaria pungens* occur in map unit 9i but not in 10a.

Escarpments associated with the Coxs, Kedumba and Grose River valleys form a more distinct boundary to this community. Species such as *E. oreades, E. dendromorpha, E. radiata* ssp. *radiata* and *Banksia spinulosa* var. *cunninghamii* are often associated with clifflines and may extend over the escarpment edge for varying distances.

Map unit 9j 'Montane Gully Forest'.

Open-forest: *Eucalyptus fastigata–E. cypellocarpa–E. dalrympleana.*

This community occupies moderate to steep, sheltered slopes and narrow gorges below the Triassic sandstone escarpments at elevations of 850 to 1100 m. It is a high altitude variant of map unit 6h and occurs on similar soils and geology (Illawarra Coal Measures). The boundary between these communities is poorly defined and for mapping purposes the 850 m contour has been used. This approximates the upper distributional limits of *Angophora costata* ssp. *costata* and *Syncarpia glomulifera* in map unit 6h, and the lower limits of *E. fastigata, E. dalrympleana* ssp. *dalrympleana* and *E. blaxlandii* in the higher altitude map unit 9j. The boundary has been mapped arbitrarily to the west of Mt Victoria township.

Eucalyptus fastigata, E. cypellocarpa and *E. dalrympleana* ssp. *dalrympleana* are dominant with *E. oreades, E. blaxlandii, E. radiata* ssp. *radiata* and *E. sieberi* in various combinations. The understorey is moderately shrubby with *Acacia terminalis, A. buxifolia, Oxylobium ilicifolium* and *Leptospermum flavescens* together with grasses and ferns such as *Culcita dubia.*

Disturbances in Community 9j include selective logging, numerous small coal and shale mines (now mostly abandoned) and landslides, particularly near Hassans Walls.

Map unit 9m 'Megalong Forest'.

Open-forest: *Angophora costata–Eucalyptus punctata–E. sieberi.*

This occurs on well-drained sandy loams derived from sandstones, conglomerates and shales of the Permian Shoalhaven Group. It covers undulating country beyond the escarpment slopes of Narrow Neck Peninsula at 400 to 750 m elevation and is also found around Mt Cookem. *Angophora costata* ssp. *costata, E. punctata* and *E. sieberi* are dominant with *E. piperita* ssp. *piperita, E. agglomerata, E. oblonga, E. eugenioides* and *E. sclerophylla* in various combinations.

The understorey includes scattered shrubs of *Persoonia linearis, P. levis, Banksia spinulosa* var. *spinulosa, Acacia obtusifolia, A. linifolia, Lomatia silaifolia, Isopogon anemonifolius* and *Leptospermum attenuatum* with a more continuous ground cover of *Lomandra longifolia, Stypandra glauca, Lepidosperma laterale* and grasses such as *Stipa pubescens, Echinopogon caespitosus, Dichelachne rara* and *Microlaena stipoides* var. *stipoides.* A more mesic understorey with occasional trees of *E. cypellocarpa* may be found in sheltered situations and where this community adjoins map unit 6h. On more clayey soils at lower elevations it is replaced by 10q.

Map unit 9n 'Montane Moist Forest'.

Open-forest: *Eucalyptus fastigata–E. dalrympleana–E. viminalis.*

The predominant plant communities at high altitudes west of Coxs River may be found on several geological formations. On moist, fertile, relatively deep clay loams and sandy loams is an open-forest characterized by *E. fastigata* and *E. dalrympleana* ssp. *dalrympleana*, occasionally with *E. viminalis, E. radiata* ssp. *radiata* and *E. bicostata* (Figure 3). *Eucalyptus viminalis* occurs sporadically on undulating terrain, but is mainly confined to creeks, while *E. radiata* ssp. *radiata* may be found on some ridgetops and where this map unit (9n) adjoins 10s. *Eucalyptus bicostata* is only found in small localized patches, for example on Binoomea Ridge, above Jenolan Caves.

The understorey includes scattered shrubs of *Acacia melanoxylon, Lomatia myricoides, Indigofera australis* and *Swainsona galegifolia*, with a continous groundcover of herbs such as *Geranium potentilloides* var. *abditum, Stellaria pungens, Hydrocotyle acutiloba, Lomandra longifolia, Gnaphalium gymnocephalum, Polystichum proliferum* and numerous grasses including *Poa labillardieri* and *Dichelachne rara*. Black (1976) recorded *E. obliqua* on the lower slopes of gullies on the eastern part of the Boyd Plateau, while the rare *E. macarthurii* can be found around the Boyd Crossing.

Community 9n may occur on Devonian rhyolites and rhyo-dacites, folded Devonian quartzites, siltstones and claystones of the Lambie Group, Silurian tuff, limestone, siltstone, phyllite and shale, and occasionally on Carboniferous adamellites, granites and granodiorites of the Kanimbla Batholith. It is most widespread on steep, sheltered slopes and gullies on the folded Devonian rocks, but also occurs on more gentle slopes of the Boyd Plateau where *E. fastigata* has been extensively logged.

Map unit 9x 'River Oak Forest'.

Open-forest: *Casuarina cunninghamiana.*

Narrow bands of *Casuarina cunninghamiana* can be found along the alluvial banks of the Coxs River. These consist of mobile gravels and sands, periodically flooded, and support little other plant life apart from short-lived exotic species such as *Conyza albida* and *Hypochoeris radicata*. The banks have a number of exotic species most notably *Conium maculatum* and *Rubus fruticosus*. The surrounding land has almost always been cleared for agriculture.

Map unit 10a 'Sydney Sandstone Complex'.

This widespread vegetation complex is found on the low elevation (<800 m) sandstone plateaux. Floristics and structure vary, depending on physiography, rainfall, altitude, aspect and local soil conditions. Two subunits have been recognized: 10ag, moist forests associated with sheltered hillsides and gullies; and 10ar, drier woodlands associated with the more exposed ridges and plateau tops. There is considerable overlap between these subunits and both grade into the higher altitude sandstone vegetation (map unit 9i) above 800 m elevation. The transition between map units 10a and 9i is discussed in the description of the latter.

Subunit 10ag Open-forest: *Angophora costata–Eucalyptus piperita–E. agglomerata–Syncarpia glomulifera.*

This subunit occurs in sheltered gullies with moist, well-drained, shallow sandy loams on Hawkesbury and Narrabeen Group sandstones. Open-forest is common on upper slopes and in the more shallow gullies. Tree species include

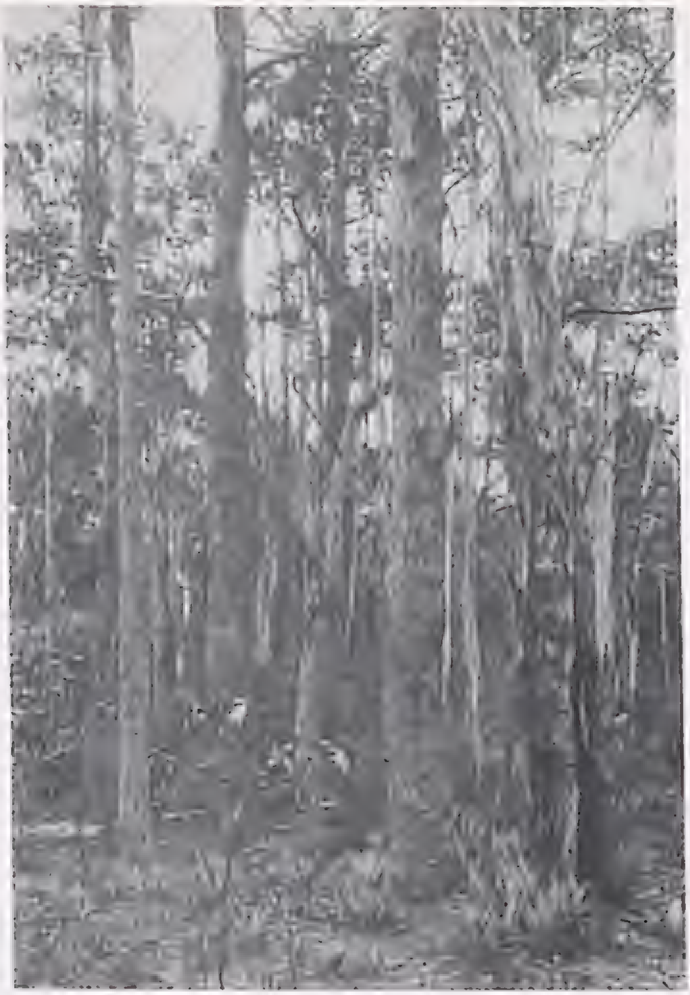

Figure 3. 'Montane Moist Forest' (map unit 9n) with rough-barked *Eucalyptus fastigata* and ribbons of decorticating bark on *E. dalrympleana* ssp. *dalrympleana* (on the right) on the Boyd Plateau near Krungle Bungle Range. The small trees are regrowth after logging. The herbaceous understorey includes the fern *Blechnum cartilagineum*.

Angophora costata ssp. *costata*, *E. piperita* ssp. *piperita*, *E. agglomerata* and *Syncarpia glomulifera* occasionally with *E. gummifera*. The understorey includes small trees of *Allocasuarina torulosa* and *Acacia elata* with shrubs *Hakea dactyloides* (single-stemmed form), *Pultenaea flexilis* and *Dodonaea triquetra*. Tall open-forest is restricted to the more sheltered gorges and is dominated by *E. deanei* with *Syncarpia glomulifera*, *Acacia elata*, *Ceratopetalum apetalum*, *Callicoma serratifolia* and *Angophora floribunda*. There is a distinctive riparian scrub of *Tristaniopsis laurina* and *Backhousia myrtifolia* along the larger watercourses.

Subunit 10ar Woodland: *Eucalyptus gummifera–E. sclerophylla–E. oblonga*.

This subunit is widespread on ridges and open slopes on shallow, well-drained, sandy soils on Hawkesbury and Narrabeen Group sandstones. Structurally, it is woodland or low woodland with trees of *E. gummifera*, *E. sclerophylla* and *E.*

oblonga, though *E. punctata, E. piperita* ssp. *piperita* and *Angophora costata* ssp. *costata* may also be present in more sheltered sites. *Eucalyptus sclerophylla* is particularly common in damper soils. The understorey is rich in shrubs of the Proteaceae, Myrtaceae and Fabaceae including *Banksia spinulosa* var. *spinulosa, Hakea dactyloides* (multi-stemmed form), *Persoonia levis, Leptospermum attenuatum, Kunzea ambigua, Pultenaea elliptica* and *Acacia linifolia.*

Map unit 10h 'Tablelands Grassy Woodland Complex'.

Woodland: *Eucalyptus dives–E. mannifera–E. eugenioides.*
Woodland: *E. pauciflora–E. rubida.*
Woodland: *E. aggregata–E. mannifera–E. stellulata.*

Above 800 m elevation on the undulating country of the upper Coxs River valley, on Shoalhaven Group geology, is a toposequence of communities. Woodland is widespread on well-drained gentle slopes and low hills. It is dominated by *E. dives, E. mannifera* ssp. *mannifera* and *E. eugenioides* with some *E. cypellocarpa* from the adjoining escarpment slope vegetation (map unit 9j). Grasses dominate the understorey, particularly *Dichelachne rara, Danthonia pilosa, Aristida ramosa* and *Stipa mollis* with emergent shrubs of *Acacia buxifolia, A. falciformis, Banksia marginata, Exocarpos cupressiformis* and *Daviesia latifolia.*

Eucalyptus pauciflora ssp. *pauciflora* and *E. rubida* occur in frost hollows, while the more poorly drained depressions, for example at Butlers Creek, may support a woodland of *E. aggregata, E. mannifera* ssp. *mannifera* and *E. stellulata* with *Leptospermum myrtifolium* in the understorey. *Eucalyptus viminalis* is common along creek banks.

This map unit has been mostly cleared for agriculture in the Hartley–Hartley Vale area.

Map unit 10l 'Snow Gum Woodland'.

Woodland: *Eucalyptus pauciflora–E. dalrympleana.*
Woodland: *E. pauciflora–E. rubida–E. stellulata.*

This unit is found at the highest altitudes on the map sheet (above 1100 m), on shallow to moderately deep loams and sandy loams derived from a variety of parent rock types, particularly acidic igneous rocks of the Kanimbla Batholith, quartzites of the Devonian Lambie Group, and more rarely on sandstones of the Shoalhaven Group.

The *E. pauciflora* ssp. *pauciflora–E. dalrympleana* ssp. *dalrympleana* woodland is found on small, exposed, rocky ridgetops west of Hampton (e.g. Mt Bindo 1364 m). The understorey consists of occasional shrubs of *Acacia dealbata* with a continous groundcover of herbs and grasses such as *Stellaria pungens, Acaena novae-zelandiae, Poranthera microphylla, Geranium* spp., *Plantago* spp., *Poa sieberiana* and *P. labillardieri.* Patches of *Lomandra longifolia* and *Pteridium esculentum* may be common.

This community is more widespread on the Boyd Plateau on undulating country, particularly where cold air drainage is significant. In hollows where drainage is poor *E. stellulata–E. pauciflora* ssp. *pauciflora* woodland occurs. *Eucalyptus rubida* may be found on the cold, dry sites (Black 1976). This unit is related to 10h.

Map unit 10m 'Mount Walker Complex'.

Woodland: *Eucalyptus macrorhyncha–E. melliodora.*

This community is found west of Lithgow and south of Hartley on dissected country at altitudes above 600 m. It is mostly on well-drained sandy loams derived from quartzite, sandstone, siltstone and claystone of the Lambie Group, but also on clays derived from a small outcrop of carboniferous gabbro. West of Lithgow

E. dives, E. viminalis and *E. bridgesiana* characterize the gullies, while *E. rossii, E. mannifera* ssp. *praecox* and *E. dives* occur on the ridges. South of Hartley there are fewer tree species. Here, *E. macrorhyncha* and *E. melliodora* occur throughout, with occasional *E. mannifera* and *E. bridgesiana* on the ridges and upper slopes.

The understorey includes scattered shrubs of *Lissanthe strigosa* and *Persoonia linearis* with a discontinuous ground cover of the grasses *Poa labillardieri, Chionochloa pallida, Aristida ramosa* and *Stipa rudis* ssp. *rudis*, and herbs including *Geranium solanderi* var. *solanderi, Hydrocotyle laxiflora, Stellaria pungens, Senecio lautus* ssp. *dissectifolius* and *Cheilanthes sieberi*.

Map unit 10o 'Yellow Box Woodland'.

Woodland: *Eucalyptus melliodora–E. viminalis.*

Much of the undulating granite country supporting this community was extensively cleared for agriculture early in the nineteenth century. Remnants may be found in the Coxs River valley at elevations between 250 and 850 m on deep, well-drained sandy soils derived from Carboniferous adamellite, granite and granodiorite.

Eucalyptus melliodora and *E. viminalis* are the most characteristic tree species, although *E. eugenioides* is particularly common east of Coxs River and *E. bridgesiana* may be found in patches throughout. *Eucalyptus dalrympleana* ssp. *dalrympleana* occurs at the higher elevations, while *Angophora floribunda* is often near watercourses or on the slopes nearby. The understorey has scattered shrubs of *Exocarpos cupressiformis, Bursaria spinosa* and *Lissanthe strigosa* with an open ground cover of grasses such as *Themeda australis, Poa labillardieri, Cymbopogon refractus* and *Echinopogon caespitosus*, and herbs including *Geranium solanderi* var. *solanderi, Hypericum gramineum* and *Lomandra glauca*.

On rocky, granite sites to the north, around Lyall Dam, *Eucalyptus dives* is particularly common and the understorey includes a greater variety of shrub species including *Banksia marginata, Platysace lanceolata, Daviesia latifolia, Dodonaea viscosa* and *Cassinia quinquefaria*.

Most of the remaining areas of Community 10o are fragmented, grazed by stock and rabbits, and weed-infested to varying degrees.

Map unit 10p 'Kowmung Wilderness Complex'.

Woodland: *Eucalyptus tereticornis–E. melliodora.*

Woodland: *E. fibrosa–E. crebra–E. eugenioides–E. punctata.*

This unit occupies a large inaccessible area of deeply dissected country with narrow ridges, steep slopes and gullies in the lower Coxs and Kowmung valleys (Figure 4). Elevation ranges from 150 to 900 m. The soils are well-drained clay loams derived from quartzites, sandstones, siltstones and claystones of the Devonian Lambie Group.

Eucalyptus tereticornis is common on moist slopes and in gullies, often with *E. melliodora*, and occasionally *E. quadrangulata. Angophora floribunda* and *E. viminalis* may be found near watercourses. The understorey is variable, though typically contains shrubs of *Bursaria longisepala, B. spinosa, Breynia oblongifolia, Lissanthe strigosa* and *Persoonia linearis* with numerous herbs including *Dichondra repens, Pratia purpurascens, Senecio lautus* ssp. *dissectifolius* and *Wahlenbergia* spp., twiners such as *Desmodium varians* and *Glycine* spp., the ferns *Cheilanthes sieberi* and *C. distans* and grasses such as *Themeda australis, Dichelachne micrantha, Oplismenus imbecillus* and *Panicum effusum*. In the east, *E. deanei* is found in moist gullies with *Angophora floribunda, E. tereticornis* and *Syncarpia glomulifera*. Occasional patches of dry rainforest (map unit 8d) may include *Toona australis*, though they are more usually dominated by *Backhousia myrtifolia*. More comprehensive field traverses would provide more data on vegetation patterns in this extensive, poorly known area.

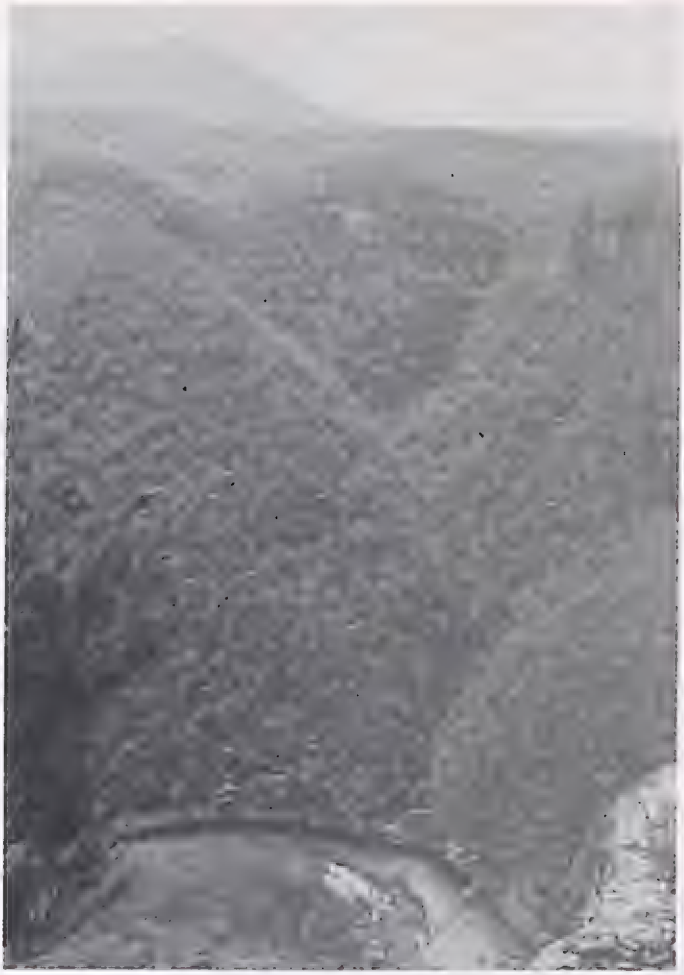

Figure 4. View northwest from Mt Cookem with Coxs River in the foreground. Eucalypt woodland in the 'Kowmung Wilderness Complex' (map unit 10p) occurs on the sides of the gorge. Note the closed canopies of *Backhousia myrtifolia* along the tributary creek, and emergent trees of *Eucalyptus deanei* nearby. The plateau surface supports 'Megalong Forest' (map unit 9m), while the slopes of the Wild Dog Mountains (background) support 'Escarpment Complex' tall open-forest (map unit 6h).

Map unit 10q 'Burragorang Ironbark Woodland'.

Woodland: *Eucalyptus crebra–E. eugenioides–E. punctata–E. fibrosa.*
Woodland: *E. sclerophylla–Angophora bakeri.*

This map unit occupies the Shoalhaven Group shales, conglomerates and sandstones below 500 m elevation, on the undulating country of the Kedumba Valley, Scotts Main Range and the Bimlow area. Gentle to moderate slopes and gullies with well-drained, loamy soils support a woodland of *E. eugenioides, E. crebra* and *E. punctata*, occasionally with *E. fibrosa* ssp. *fibrosa* and *E. agglomerata*. The understorey is open with scattered shrubs including *Jacksonia scoparia, Persoonia linearis, Acacia buxifolia, Grevillea obtusifolia* and *Lissanthe strigosa* and a ground cover of *Stypandra glauca, Lomandra longifolia, Themeda australis, Aristida vagans* and *Imperata cylindrica*.

Trees of *E. tereticornis*, with shrubs of *Melaleuca linariifolia* and a grassy understorey are found on damp, low-lying clay-loam soils and in gullies.

Exposed rocky ridges with shallow, sandy soils and western aspects, support woodland of *E. sclerophylla* and *Angophora bakeri* ssp. *bakeri* and an understorey of low shrubs including *Banksia spinulosa* var. *spinulosa, Leptospermum parvifolium, Dillwynia retorta, Mirbelia rubiifolia, Phyllanthus thymoides* and *Daviesia acicularis*. Grasses incude *Stipa pubescens* and *Aristida warburgii*.

Map unit 10r 'Residual Sandstone Woodland'.

Woodland: *Eucalyptus sieberi–E. blaxlandii.*

This community is found in well-drained, shallow, sandy soils on residual sandstone cappings of the Shoalhaven Group, folded sandstones of the Devonian Lambie Group and occasionally on Carboniferous granites. There are small occurrences at elevations above 900 m along moderately exposed, rocky ridges and plateau edges west of Coxs River, for example Table Mountain and parts of Black Range. *Eucalyptus sieberi* and *E. blaxlandii* are the dominant tree species here, though the latter may be absent from some sites. *Eucalyptus cypellocarpa* occurs on parts of Gibraltar Rocks and Black Range (Figure 5). Understorey shrubs include *Leptospermum attenuatum, Banksia marginata, B. spinulosa* var. *spinulosa, Persoonia linearis, P. laurina, Acacia obtusifolia, A. obliquinervia, Oxylobium ilicifolium, Leucopogon lanceolatus* var. *lanceolatus, Brachyloma daphnoides, Monotoca scoparia* and *Platysace lanceolata*. Ground cover species include *Gonocarpus tetragynus, Pomax umbellata, Lomandra glauca, L. longifolia* and *Patersonia glabrata*. The shrubby understorey and low frequency of grasses distinguishes Community 10r from other high altitude vegetation types in the area.

Though more common on sandstone of the Shoalhaven Group, this community is also found on sandstone facies of the Lambie Group on narrow rocky ridges such as Krungle Bungle Range and the eastern end of Black Range. Flatter sites on the Shoalhaven Group sandstones (e.g. the western end of Black Range) are occupied by map unit 10s which is more widespread on the Lambie Group metamorphics and Carboniferous granites. Intermediate sites support *E. sieberi* and *E. radiata* ssp. *radiata* with an understorey mostly of grasses and scattered shrubs.

The most northern occurrence of Community 10r is west of Old Bowenfels where residual sandstone of the Illawarra Coal Measures caps a remnant of Shoalhaven Group sandstone. *Eucalyptus sieberi* is the only tree species on the upper part of this outcrop, while on the lower slopes it occurs with *E. dives*. The latter may be a remnant of Community 10h which probably once grew on the flat surrounding country now cleared for agriculture.

Map unit 10s 'Montane Woodland'.

Woodland: *Eucalyptus radiata–E. dalrympleana.*

Woodland: *E. ovata–E. stellulata.*

This map unit is found on flat to undulating country, west of Coxs River, at elevations above 900 m. It occurs on well-drained to damp sandy loams on various parent rocks including quartzite, sandstone, siltstone and claystone of the Lambie Group (Devonian), adamellite, granite and granodiorite of the Kanimbla Batholith (Carboniferous) and shale, conglomerate and sandstone of the Shoalhaven Group (Permian). It is most widespread on the Devonian parent material on moderate slopes, though generally more luxuriant on the Carboniferous granites. On both types of geology it grades into unit 9n in sheltered sites.

Black (1976) described this community in her survey of the Boyd Plateau. *Eucalyptus radiata* ssp. *radiata and E. dalrympleana* ssp. *dalrympleana* are the

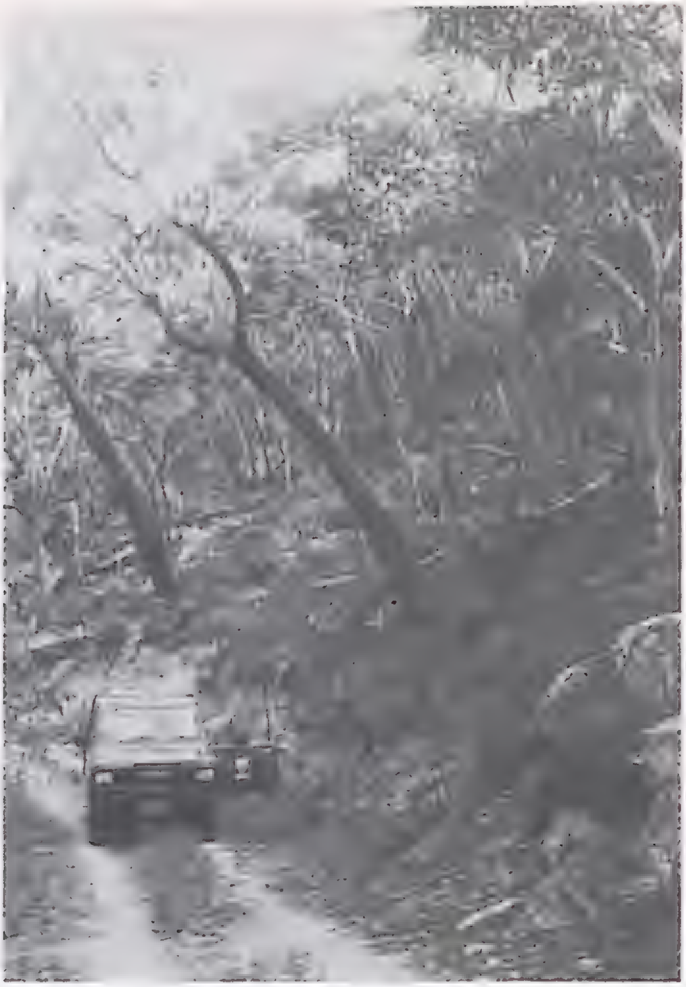

Figure 5. Woodland with *Eucalyptus sieberi, E. cypellocarpa* and a shrubby understorey interspersed with clumps of *Poa* sp. on granite at Moorara Boss, nothern Boyd Plateau (map unit 10r).

dominant canopy species, though there are significant numbers of *E. dives* on the north-western part of the Boyd Plateau, and *E. pauciflora* ssp. *pauciflora* may be found sporadically throughout, particulary at higher elevations (Figure 6). The understorey includes scattered shrubs of *Acacia obliquinervia, Leucopogon lanceolatus* var. *lanceolatus, Lomatia myricoides* and *Persoonia oxycoccoides* with a relatively continuous ground cover of grasses such as *Poa sieberiana, P. labillardieri* and *Dichelachne rara* and herbs such as *Lomandra longifolia, Gonocarpus tetragynus, Wahlenbergia communis* and *Hydrocotyle* sp.

Trees of *E. ovata*, sometimes with *E. stellulata* , are found in poorly-drained depressions. The understorey includes *Leptospermum obovatum, Gahnia sieberiana, Juncus melanobasis, Restio fimbriatus* and *Blechnum minus.*

Map unit 10t 'Mount Blaxland Complex'.

Woodland: *Eucalyptus sieberi–E. pulverulenta.*

Found on shallow sandy loams, this vegetation is restricted to the steep, rocky knolls on Mt Blaxland and Wentworths Sugarloaf (west of Hartley) and an outcrop of Devonian rhyolite near Lowther. A woodland dominated by *E. sieberi, E. rossii* and *E. oblonga* with the shrubby *E. pulverulenta* as an understorey species is most common, though in places the trees are absent, leaving *E. pulverulenta* in open-heath vegetation (T. J. Fatchen, pers. comm.). *Eucalyptus pulverulenta* occurs naturally only in the Hartley district and at Cowra Creek, east of Bredbo (Pryor 1981).

The understorey consists of an open shrub layer of *Persoonia linearis, Dodonaea viscosa, Bursaria spinosa, Platysace lanceolata, Acacia verniciflua, A. buxifolia* and *Oxylobium ilicifolium* with a ground cover of grasses including *Themeda australis, Poa* spp., *Danthonia* spp., and *Stipa* sp., and herbs such as *Stypandra glauca, Dianella revoluta, D. caerulea, Lomandra longifolia, L. multiflora* and *Helichrysum bracteatum* (T. J. Fatchen, pers. comm.).

Map unit 10u 'Jenolan Granite Woodland'.

Woodland: *Eucalyptus punctata–E.* sp. nov. 'MAHEK'– *E. sieberi.*

A granite outlier of the Kanimbla Batholith on the steep, north-facing slope of Jenolan Gorge supports this distinctive and diverse woodland community which grades into Community 10r on the highest parts of the outcrop (>1000 m). The soils are relatively deep, freely draining and sandy. Open situations are occupied by *E. punctata, E.* sp. nov. 'MAHEK' and *E. sieberi with some E. goniocalyx* at higher elevations while *E. melliodora, E. agglomerata, E. cypellocarpa, E. punctata* and *Angophora floribunda* may be found in more sheltered situations in various combinations.

The understorey is predominantly shrubby with *Exocarpos strictus, Dillwynia retorta, D. acicularis, Bossiaea obcordata, Banksia spinulosa* var. *spinulosa, Grevillea arenaria, Platysace lanceolata, Leptospermum parvifolium, L.* sp. nov. 'X', *Leucopogon muticus, Teucrium corymbosum* and *Xanthorrhoea australis.* This is also an interesting disjunct Tableland locality for *Melaleuca armillaris,* essentially a coastal species, first collected from Jenolan Gorge by Blakely in 1900.

Map unit 17a 'Black Range Scrub'.

Open-scrub: *Eucalyptus mannifera–Leptospemum myrtifolium– L.* sp. nov. 'A'–*Patersonia fragilis.*

On the gentle southern slopes of Black Range are several small, poorly-drained areas with rather humic, loamy soils overlying metamorphic rocks of the Devonian Lambie Group. Shrubs of *Leptospermum myrtifolium* and *L.* sp. nov. 'A' predominate here with occasional small trees of *E. mannifera* ssp. *mannifera, E. dalrympleana* ssp. *dalrympleana* and *E. stricta.* Sedges such as *Gahnia sieberiana, Schoenus apogon, Empodisma minus* with other moisture tolerant herbs including *Patersonia fragilis, Gonocarpus micranthus* ssp. *micranthus* and *Viola hederacea* comprise the gound cover.

This community resembles the swamps of the Boyd Plateau (map unit 26b), though the latter lack eucalypts and are more thickly vegetated with *Carex* spp. and *Juncus* spp., probably due to greater waterlogging.

Map unit 20a 'Newnes Plateau Shrub Swamps'.

Closed-heath: *Leptospermum lanigerum–Baeckea linifolia–Grevillea acanthifolia–Xyris ustulata.*

In shallow headwater valleys above 1000 m elevation on the Triassic sandstone plateau, swamps with poorly-drained, acid, sandy peat soils have developed. On the Katoomba 1:100 000 map sheet these are restricted to the Bell area, although their best development is on the Newnes Plateau to the north.

These swamps are dominated by a closed-heath of *Leptospermum lanigerum, Baeckea linifolia, Grevillea acanthifolia* and *Epacris paludosa* with a ground cover

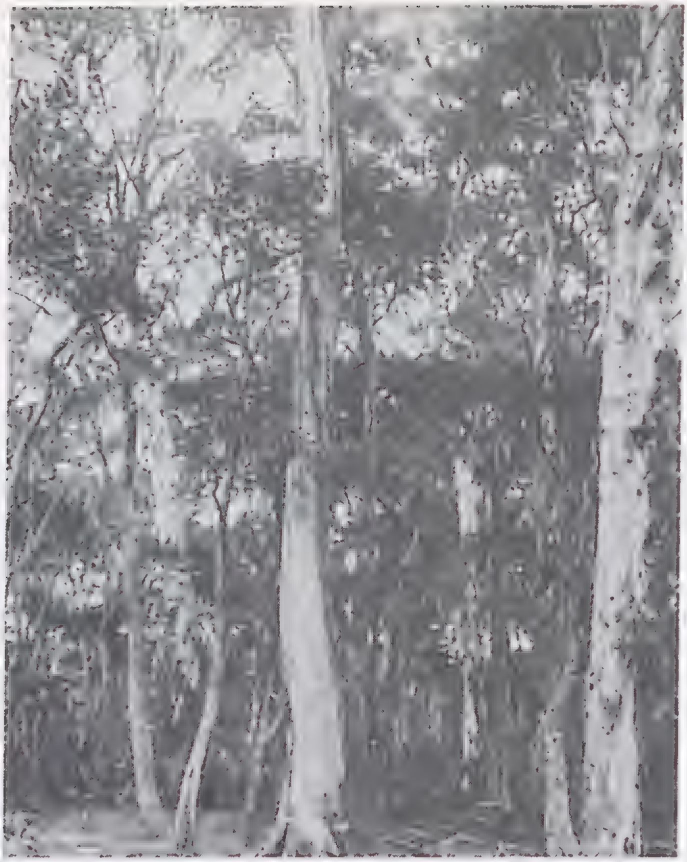

Figure 6. *Eucalyptus radiata* ssp. *radiata* (rough barked) and *E. dalrympleana* ssp. *dalrympleana* (smooth barked) with a grassy understorey of *Poa sieberiana* in 'Montane Woodland' (map unit 10s) near Sally Camp Creek on the Boyd Plateau.

of sedges including *Restio australis, Empodisma minus, Lepyrodia scariosa, L. anarthria, Lepidosperma limicola* and *Patersonia fragilis.* Floristic composition varies according to soil type and waterlogging regime. Adjacent to drainage lines there may be particularly thick growth of *Gymnoschoenus sphaerocephalus* and *Gleichenia dicarpa*, while in relatively drier, more open sites are small herbs such as *Hydrocotyle acicularis, Viola hederacea, Gonocarpus tetragynus* and *Xanthosia dissecta.*

Where the soils have a higher clay content these swamps contain a number of species also found in the swamps of the Boyd Plateau (map unit 26b) including *Leptospermum myrtifolium, L. flavescens, Callistemon sieberi, Juncus continuus* and, in drier places, *Lomandra longifolia.*

Map unit 20b 'Coxs River Swamps'.

Closed-heath: *Leptospermum obovatum–L. juniperinum–Grevillea acanthifolia.*

Filled with rather clayey, organic sediments derived from the Illawarra Coal Measures, these swamps occur where creeks draining the Triassic sandstone plateau dump their sediment load at the base of the escarpment. They support a simple flora dominated by *Leptospermum obovatum, L. juniperinum* and

Grevillea acanthifolia with a dense groundcover of *Carex* spp. and *Juncus* spp. Kerosene Creek at Hartley Vale and smaller swamps near Nellies Glen are the only examples in the area covered by the Katoomba 1:100 000 map sheet, though others are found in the headwaters of Coxs River to the north. Grazing at Kerosene Creek has led to the invasion of some exotic species and some damage due to trampling by stock.

Map units 21c & 21f 'Open-heath'.

Heath is found on exposed ridgetops, upper slopes with western aspects and often above the escarpment cliffs on the Triassic sandstone plateau (Figures 2 and 7). It occupies an altitudinal range from 600 to 1250 m. The soils are well drained to periodically damp, skeletal, pale and sandy, low in nutrients and derived from Narrabeen Group Sandstones.

Throughout the broad geographical and altitudinal range of the heath communities a number of species are common, particularly the shrubs *Eucalyptus stricta, Allocasuarina nana, Leptospermum attenuatum, Isopogon anemonifolius, Petrophile pulchella, Lambertia formosa, Conospermum taxifolium, Hibbertia cistiflora* and *Platysace linearifolia,* and ground cover species such as *Lepidosperma viscidum, Schoenus villosus, Entolasia stricta, Lomandra glauca, Gonocarpus tetragynus, Dampiera stricta, Goodenia bellidifolia* and *Sowerbaea juncea.* In contrast, the distributions of many other species are more restricted and form part of an overall altitudinal gradation in species composition. An elevation of 850–900 m has arbitrarily been chosen to separate the high and low altitude heath communities, coded 21c and 21f respectively.

Map unit 21c 'Montane Heath'.

Open-heath: *Eucalyptus stricta–Allocasuarina nana–Leptospermum attenuatum–Phyllota squarrosa–Eriostemon obovalis.*

Open-heath: *Epacris reclinata–Dracophyllum secundatum–Gleichenia rupestris.*

High elevation heath may be found on Narrabeen Group sandstones from Narrow Neck Peninsula to the Newnes Plateau in the north, particularly on Flat Top, Hat Hill, around Blackheath, the Mt Banks–Bell area and Hassans Walls. The dominant shrubs include *Eucalyptus stricta, Allocasuarina nana* and *Leptospermum attenuatum* with prominent ground cover species such as *Schoenus villosus, Lepidosperma viscidum, Patersonia sericea* and *Goodenia bellidifolia.* Species restricted to higher elevations include *Eriostemon obovalis, Boronia anemonifolia, B. microphylla, Acacia gunnii, Mirbelia platyloboides, Phyllota squarrosa, Pultenaea canescens, Darwinia taxifolia* ssp. *taxifolia, Eucalyptus mannifera* ssp. *gullickii, Petrophile canescens, Pseudanthus divaricatissimus* and *Omphacomeria acerba.*

A distinctive flora grows on the cliff faces and rock overhangs associated with the heaths of the plateau edge. These rock faces receive seepage moisture, and are particularly rich in epacrids such as *Epacris reclinata, Dracophyllum secundatum* and *Sprengelia monticola* and the fern, *Gleichenia rupestris.* The endangered species *Microstrobos fitzgeraldii* is a notable inhabitant of rock faces within the spray zone of waterfalls (Smith 1981).

Map unit 21c occurs on Shoalhaven Group sandstones on Ti Willa Plateau and Kanangra Tops, while on exposed south-eastern parts of the Boyd Plateau it may be found on metamorphic rocks of the Devonian Lambie Group. The latter is characterized by tall, thick growth of *Eucalyptus stricta,* often forming a closed-scrub with occasional shrubs of *Banksia marginata, Acacia dorothea, Isopogon anemonifolius* and *Allocasuarina nana* below. By contrast, *E. stricta* is absent from much of Kanangra Tops where thickets of *Allocasuarina nana* and

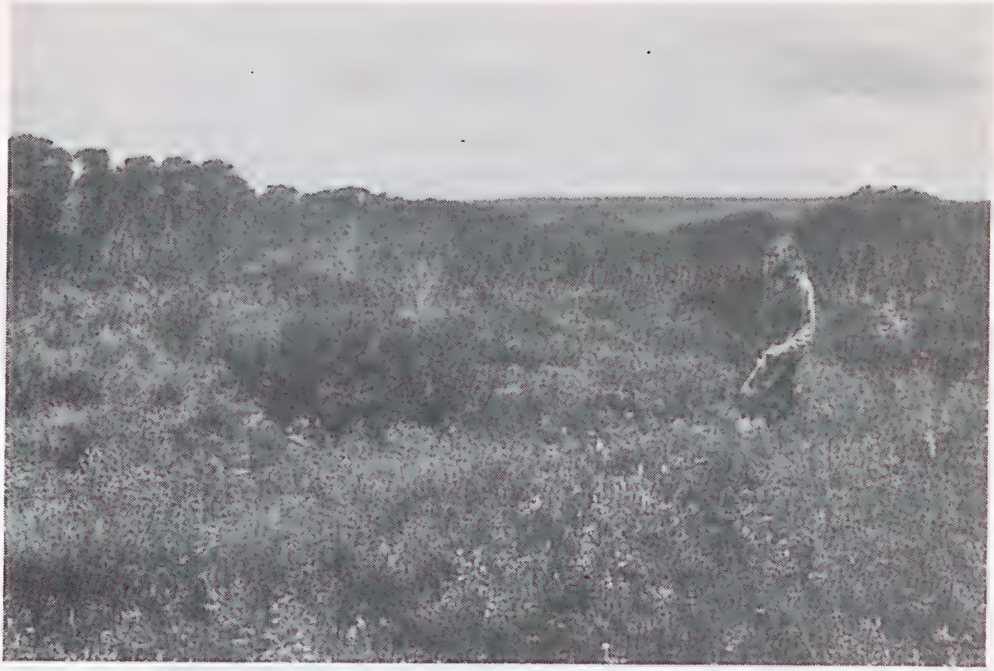

Figure 7. 'Montane Heath' on Mt Thurat (map unit 21c) showing *Banksia marginata, Epacris microphylla* (flowering) and *Dillwynia phylicoides*, with clumps of *Eucalyptus stricta* in the background.

bare rock platforms alternate with *Baeckea brevifolia* on shallow humic soils in poorly-drained depressions. Several species noted on Kanangra Tops, including *Prostanthera saxicola* var. *montana* and *Leptospermum* sp. nov. 'Y' were not found on the heaths of the Blue Mountains Plateau to the east. However, these western heaths generally show lower species richness than those of the Blue Mountains.

Map unit 21d 'Pagoda Rock Complex'.

Open-heath: *Allocasuarina nana–Leptospermum arachnoides–Lepidosperma viscidum.*

Open-scrub: *Eucalyptus* sp. nov. 'MOKII'.

Woodland: *E. sieberi–E. piperita.*

This mosaic of vegetation types is found in the Wollangambe Wilderness amongst the 'beehive' or 'pagoda' formations of the Narrabeen Group sandstones (Benson 1984). On the exposed, rocky outcrops is an open-heath of *Allocasuarina nana, Leptospermum arachnoides, Platysace lanceolata* and *Banksia ericifolia*, sometimes interspersed with clumps of the mallee, *Eucalyptus* sp. nov. 'MOKII', though generally resembling map unit 21c. In more sheltered situations there is woodland, similar to map unit 9i, with *E. piperita* ssp. *piperita, E. sieberi, E. oblonga* and *E. sclerophylla.* Common understorey species include *Daviesia latifolia, Dillwynia retorta, Acacia terminalis, A. dorothea, Boronia microphylla, Hakea dactyloides* and *Allocasuarina distyla.*

Map unit 21f 'Lower Blue Mountains Heath'.

Open-heath: *Eucalyptus stricta–Allocasuarina nana–Leptospermum attenuatum–Phyllota phylicoides–Eriostemon hispidulus.*

Open-heath: *Epacris reclinata–Dracophyllum secundatum–Gleichenia rupestris.*

This heath community occurs below 850–900 m elevation on Kings Tableland, Sublime Point, Linden Ridge and in the Mt Hay area. The most conspicuous species include many of the 'ubiquitous' heath species common in Community 21c. However, a number of small shrubs including *Epacris rigida, Hemigenia purpurea, Daviesia corymbosa, Phyllota phylicoides, Pultenaea elliptica, Darwinia fascicularis* ssp. *oligantha*, and the sedge, *Lepidosperma neesii* may be regarded as typical low elevation constituents.

Cliff faces and rock overhangs support a similar flora to that described for map unit 21c.

Map unit 26a 'Blue Mountains Sedge Swamps'.

Closed-sedgeland: *Gymnoschoenus sphaerocephalus–Lepidosperma limicola–Xyris ustulata–Baeckea linifolia.*

In contrast to the shrub swamps of the Upper Mountains (map unit 20a), swamps in the headwater valleys of the sandstone plateau below 1000 m elevation, are dominated by sedges. These swamps occupy steep-sided basins, up to 35 ha in area. The upper boundary is often a clearly defined rim coinciding with the outcropping of a claystone stratum. This acts as an aquiclude (Holland 1974) and directs water to the surface at the rim to form a swamp below (Figure 8).

Swamps on steep valley sides (often known as hanging swamps) are intermittently waterlogged and have shallow, sandy soils with a moderate organic content. They have open-heath vegetation with shrubs of *Hakea teretifolia, Leptospermum squarrosum, Epacris obtusifolia, E. microphylla, Sprengelia incarnata, Hibbertia cistiflora, Dampiera stricta* and *Pultenaea incurvata*, and sedges such as *Ptilanthelium deustum, Leptocarpus tenax, Empodisma minus* and *Lepyrodia scariosa*. In contrast, valley bottoms support closed-sedgeland on finer grained, deeper, highly organic sediments that are frequently waterlogged and permanently wet. There are fewer species here than on the more freely-draining slopes, characteristically *Gymnoschoenus sphaerocephalus, Lepidosperma limicola, Empodisma minus* and *Xyris ustulata* with occasional shrubs of *Baeckea linifolia, Leptospermum lanigerum, Acacia ptychoclada* and *Pultenaea divaricata.*

In some cases there is a distinct wet heath/woodland (map unit 9i) vegetation boundary but in others, there is a broader transition zone from wet heath to dry heath (map unit 21f).

Map unit 26b 'Boyd Plateau Bogs'.

Closed-sedgeland: *Carex appressa–C. gaudichaudiana–Juncus holoschoenus–Baeckea utilis.*

Closed-heath: *Leptospermum myrtifolium–L. obovatum–L. lanigerum.*

Swamps in headwater valleys on the Boyd Plateau are entirely different to those on the Blue Mountains sandstone plateau (map unit 26a). They occur at higher altitudes (ca. 1200 m), consist of soils derived from granite parent material, probably with a higher nutrient status, and occupy relatively shallow valleys compared to the hanging swamps in the Blue Mountains.

Vegetation patterning within the Boyd swamps appears to relate primarily to waterlogging regimes, but has probably also been affected by fire and grazing. The most widespread vegetation type is a closed-sedgeland of *Carex appressa, C. gaudichaudiana, Juncus holoschoenus* ssp. *fockei, Restio australis, Agrostis hiemalis* and *Deyeuxia gunniana* with other herbs including *Patersonia fragilis, Asperula gunnii* and *Geranium neglectum* and emergent shrubs of *Epacris paludosa, Hakea microcarpa* and *Baeckea utilis.* Thickets of *Leptospermum myrtifolium, L. lanigerum, L. obovatum* and *Callistemon sieberi* may occur

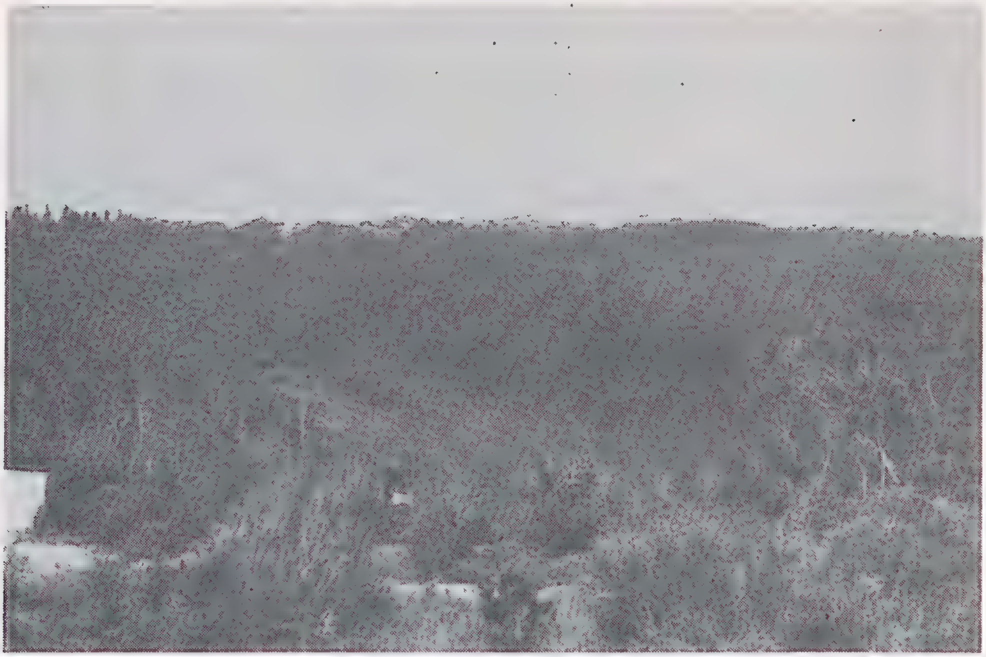

Figure 8. Kings Tableland, a plateau of Narrabeen Sandstone, showing *Eucalyptus sieberi* woodland (map unit 9i) on upper slopes grading into 'Montane Heath' (map unit 21c) in right background. The 'Sedge Swamp' (map unit 26a) has a clearly defined boundary with the woodland above, related to the outcropping Wentworth Falls Claystone.

sporadically, while more open areas with *Amphipogon strictus, Empodisma minus, Lepidosperma filiforme, Wahlenbergia ceracea* and *Helichrysum bracteatum* can often be seen around the margins.

The presence of species such as *Celmisia* sp. aff. *longifolia, Wahlenbergia ceracea* and *Sphagnum* sp. indicates that the Boyd swamps share floristic affinities with the alpine and subalpine bogs of the Southern Tablelands.

Discussion

Vegetation patterns

The patterns of vegetation in the area covered by the Katoomba map sheet relate to soils, physiography and elevation, and in particular to geology. Cross-section diagrams on the map sheet depict the relationships between vegetation and geology. Many plant communities are found only on particular soil types and are directly related to their parent geology. For example, communities in map units 6d and 9x are restricted to river alluvium, those in 6c and 6g relate to diatremes and basalt flows respectively, while map unit 9a is found only on ridges capped by Wianamatta Shale, and units 26a and 26b are restricted to waterlogged soils derived from sandstone and granite respectively. Carne (1908) aptly remarked,

> 'The influence of geological conditions on botany is so pronounced and distinctive in insular areas on the sandstone plateau as to arrest the attention even of those unfamiliar with the cause . . . '

On the western part of the map area, however, the major map units (9n, 10r, 10s and 10l) occur on two or more different geological substrates. This may be due to the derivation of a similar range of soil types from the different rocks or the overriding effect of the cold climate restricting the number of species able to grow in this area.

Physiography influences the degree of exposure, soil formation and the availability of water at a particular site. Extreme examples are heath communities (map units 21c and 21f) found on exposed ridge crests, and rainforests (8c and 8d) which are found in moist, well sheltered gullies and slopes. Floristic differences between subunits 10ag and 10ar relate specifically to their different physiographic environments as they occur on the same parent material in similar climatic conditions.

There is a significant variation in rainfall, minimum temperatures and the occurrence of frosts and snow over the altitudinal range in the area covered by the Katoomba sheet. Groups of communities on similar soils, geology and physiography may form altitudinal series. For example, 10a–9i–10r on sandstone plateaux, 6h–9j on Permian escarpments, 10q–9m–10h on undulating Shoalhaven Group sediments, 21f–21c on exposed sandstone ridges and 26a–20a in sandstone headwater valleys. The Blue Mountains area offers excellent opportunities for research on the relationships between species distributions and altitudinal gradients.

Conservation

Large areas of natural vegetation on the Katoomba map sheet have been dedicated as reserves for nature conservation. Some 140 000 ha are included within Blue Mountains and Kanangra-Boyd National Parks (Figure 9). Smaller reserves include the Forestry Commission's proposed Forest Preserve at Beefsteak Creek near Black Range and several important Council Reserves in the Blue Mountains, including Waterfall Reserve at Mt Wilson and Coachwood Glen at Blackheath. Regrettably some of these reserves cannot always guarantee the long term protection and management of the biological resources they contain. In particular, Council Reserves and Forest Preserves may be subject to changes in zoning and local management priorities. Plant communities can only be regarded as adequately conserved if representative samples of their geographic and ecological ranges are included within Nature Reserves, National Parks or Flora Reserves, as these are protected by State legislation.

Plant communities in the Katoomba region are not evenly represented within the reserve system (Table 3). In fact five map units (9i, 10ag, 10ar, 10p and 10q) account for most of the area covered by the two National Parks. Ten of the 32 Katoomba map units are not represented in reserves at all. They are 6d, 9a, 9j, 9x, 10h, 10m, 10o, 10t, 17a and 20b. A further six (6c, 8c, 8d, 10r, 20a, 21d) are represented by only small examples in reserves.

A number of the larger poorly conserved map units persist as remnants in the Coxs River valley. 'Yellow Box Woodland' (map unit 10o) has been extensively cleared for agriculture around Hartley. Part of the largest remnant in the Little River area is the subject of the National Parks Association's proposed Little/Coxs River Addition to Kanangra-Boyd National Park (Byrne 1987). This is the only opportunity to conserve a sample of 'Yellow Box Woodland' in the Katoomba area. The 'Tablelands Grassy Woodland Complex' (map unit 10h) has also been largely cleared though small areas persist around Hartley Vale. Larger unprotected remnants are found to the north around Ben Bullen, Cullen Bullen and west of Lidsdale. 'Coxs River Swamps' (map unit 20b) have a naturally restricted distribution. Unprotected examples are found near Nellies Glen, at Kerosene

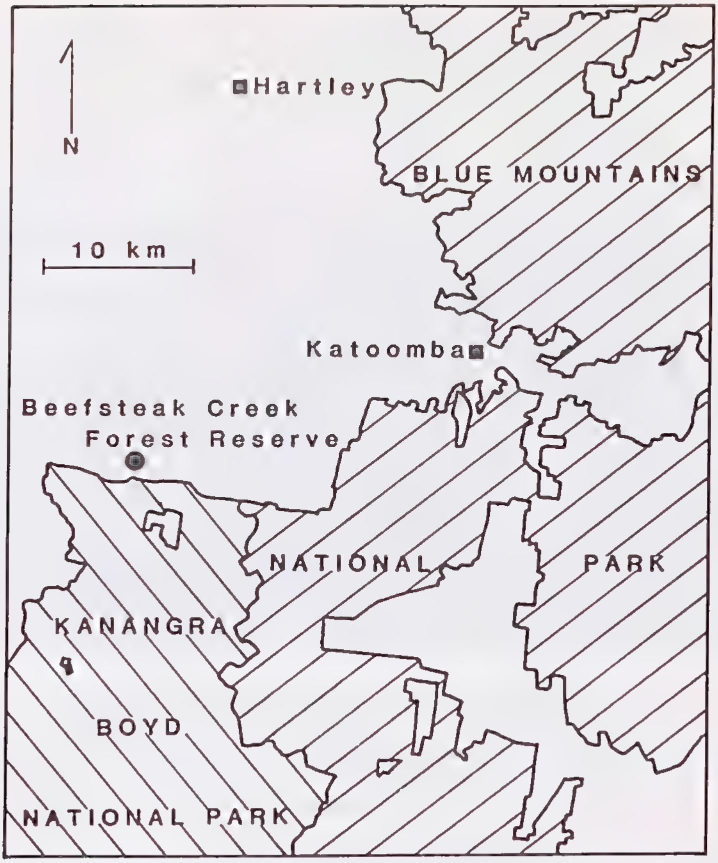

Figure 9. Location of conservation reserves in the area covered by the Katoomba map sheet.

Creek, and to the east of Cullen Bullen, further north (Benson 1984). These swamps are affected by grazing to varying degrees. 'River Oak Forest' (map unit 9x), although remnants are usually weed-infested, has survived in many places along the banks of Coxs River in the predominantly agricultural Megalong Valley. Smaller, unmapped stands occur downstream in the Blue Mountains National Park, while larger areas are found further south along the Wollondilly River.

Map unit 10m, although unprotected, has remained relatively undisturbed because of its rough terrain and unsuitability for agriculture. The National Parks Association of New South Wales has a Nature Reserve proposal for an area west of Lithgow. If this proceeds this vegetation will be adequately conserved. Large unprotected areas of map unit 9j remain on the escarpment slopes between Mount Victoria and Lithgow. These have been selectively logged in places, but remain relatively undisturbed due to their rough terrain. Numerous gullies supporting this vegetation are found in the south-west of Wollemi National Park.

Most of the other poorly-conserved map units have naturally restricted distributions. Map units 6d and 10t have very restricted distributions and occur only on private property in the Kedumba and Coxs River valleys respectively. 'Shale Cap Forest' (map unit 9a) is also restricted to small areas on private property and has been largely cleared for agriculture. A small stand of somewhat similar vegetation is conserved in Wollemi National Park at Culoul Range (Benson 1980).

Table 3: Major conservation reserves in the area covered by the Katoomba 1:100 000 vegetation map sheet.

Reserve	Administered by	Approximate area (ha)	Map units included
Blue Mountains National Park	NP&WS	100 000	6c*, 6g, 6h, 8c*, 8d*, 9i, 9m, 10ag, 10ar, 10p, 10q, 20a*, 21c, 21d*, 21f, 26a
Kanangra-Boyd National Park	NP&WS	40 000	9n, 101, 10p, 10r*, 10s, 10u, 17a, 21c, 26b
Beefsteak Creek Forest Preserve (Proposed)	FC	200	9n, 10s

Map units not represented: 6d, 9a, 9j, 9x, 10h, 10m, 10o, 10t, 17a, 20b

* represented by small examples only

NP&WS = National Parks and Wildlife Service

FC = Forestry Commission of New South Wales

Other areas of this community have been almost completely cleared from the ridges around Springwood. ‘Montane Rainforest’ (map units 8c) and ‘Moist Basalt Cap Rainforest’ (map unit 6g) also have restricted distributions. Small areas are represented in Blue Mountains and Wollemi National Parks, though much of the remainder occurs in Council Reserves at Mount Wilson and Coachwood Glen (Pulpit Hill Creek, Blackheath). Similarly, small areas of map unit 10r are represented in Kanangra-Boyd National Park while a number of other remnants are found further north in forestry and agricultural areas at Black Range, Gibraltar Rocks, Table Mountain, Mount Arthur, Cheetham and Old Bownfels.

Small ‘Newnes Plateau Shrub Swamps’ (map unit 20a) occur in Blue Mountains National Park near Bell, though much larger examples of these interesting swamps remain unprotected on the Newnes Plateau to the north (Benson 1984). Other restricted types include ‘Black Range Scrub’ (map unit 17a), found only in Jenolan State Forest; ‘Glen Forest’ (6c), represented by very small stands in Blue Mountains National Park; and ‘Kowmung Dry Rainforest’ (8d), restricted to Kanangra-Boyd National Park.

Plant communities on the Triassic sandstone plateau are generally well conserved. However, the area between Wentworth Falls and the Kedumba Valley gate on Kings Tableland warrants special consideration. The heath in this area (part of map unit 21f) represents an important part of the overall altitudinal sequence in Blue Mountains heath communities. At an elevation of 830–880 m it represents an intermediate position where a number of high and low altitude heath species co-exist. Nineteen rare or significant species (Table 4) are also found in this area.

Sixty-five significant species are listed for the Katoomba map sheet area (Table 4), 41 of which are also listed by Leigh, Briggs & Hartley (1981). These species are either rare, threatened or of botanical significance in terms of geographic distribution. The list contains species of varying rarity and conservation status: *Olearia oliganthema* has not been collected since 1866 and is presumed to be extinct (Leigh, Briggs & Boden 1984); *Microstrobos fitzgeraldii* is vulnerable and threatened (Smith 1981); *Melaleuca armillaris*, although common in coastal situations is restricted on the tablelands; while *Hibbertia saligna* appears to be adequately conserved with numerous populations in the Blue Mountains

National Park. There are a high number of locally restricted species for the map area, and particularly along the escarpment from Kings Tableland, through Wentworth Falls, Leura and Katoomba to Narrowneck Peninsula. Workers involved in the preparation of environmental impact statements, plans of management, conservation studies etc., should be aware of the significance of these species if present in their study area.

The number of significant plant communities and species found in the area covered by the Katoomba map sheet is high when compared with other parts of the Sydney region (lists for Gosford–Lake Macquarie, St Albans, Wallerawang, Sydney and Penrith map sheets are held at the Royal Botanic Gardens, Sydney). Twenty of the 65 significant species listed in Table 4 are endemic to the greater Blue Mountains region. Bearing in mind the strong altitudinal trends in the vegetation, the restricted distributions of many species may be related to climatic fluctuations in the past. Many species now restricted to higher elevations may have been more widespread in cooler times, particularly those which are represented by disjunct populations.

Management issues

Despite the large area set aside to protect the natural environment, the concentration of suburban development along the major linear ridge systems followed by the Great Western Highway and Bells Line of Road will have a long-term impact on a proportionally greater area. The main effects on vegetation, apart from the obvious direct impact of future clearing, will be through increasing effluent runoff from adjacent built-up areas (Bliss, Riley & Adamson 1983). This contains silt and nutrients which promote the invasion of exotic weed species, such as *Lonicera japonica* and *Ligustrum* species, into previously undisturbed bush. The heads of many creeks and gullies around Katoomba and Wentworth Falls already have a high component of exotic species. This is a serious and increasing problem that needs further documentation and treatment.

The other main effects of adjacent development are from changes in the bushfire regime, which may be either reduced or increased depending on the site. Either way the vegetation may be changed, and it is only with continuing research into the response of native plant communities and individual species to fire, that predictions and successful management of thèse impacts can be accomplished.

Acknowledgements

We would like to thank Bob Coveny and the botanists of the National Herbarium of New South Wales for plant identifications and comments on the manuscript, Richard McRae for sharing with us his knowledge of the area, Tracey Goodwin, Helen Cumming, Micheal Doherty, John Steer, Nining McCann, Jocelyn Howell, Tanya McGree and Jenny Collins for technical assistance with data compilation and cartography, and Roger Lembit for assistance with field checking. We also appreciate the cooperation of staff of the National Parks and Wildlife Service and the Metropolitan Water Sewerage and Drainage Board.

Table 4: Species of particular conservation significance within the Katoomba 1:100 000 map sheet area.

Species listed here are either rare or threatened (Leigh, Briggs & Hartley, 1981), or of botanical significance in terms of geographic distribution. Localities refer to Katoomba map sheet occurrences. Nth. = northern, Sth. = southern, codings (2X, 2V, 2VC, 3V, 2RC, 3RC, 2K) are from Leigh, *et al.* (1981).

Species (family)	Habitat/Locality	Significance
FERNS		
ASPIDIACEAE		
Lastreopsis hispida	Rainforest, Mt Wilson	Local disjunct population
BLECHNACEAE		
Blechnum gregsonii	Lawson, Mt Wilson, Wentworth Falls	2V
HYMENOPHYLLACEAE		
Hymenophyllum pumilum	Rainforest, Mt Tomah	3RC, very rare
Sphaerocionium lyallii	Rainforest, Wentworth Falls	3RC
GYMNOSPERMS		
PODOCARPACEAE		
Microstrobos fitzgeraldii	Within spray of waterfalls, Wentworth Falls to Katoomba	2V, highly restricted local endemic
DICOTYLEDONS		
APIACEAE		
Xanthosia dissecta	Swamps, Wentworth Falls	Local disjunct population
ASTERACEAE		
Celmisia sp. nov. aff. *longifolia*	Wentworth Falls, Blackheath	Local disjunct population
Olearia oliganthema	Blue Mountains	2X, local endemic
Olearia quercifolia	Swamps, Wentworth Falls to Clarence	2RC, local endemic
CAMPANULACEAE		
Wahlenbergia ceracea	Swamps, Boyd Plateau	Local disjunct population
CUNONIACEAE		
Acrophyllum australe (Calycomis australis)	Woodford–Linden	3V, local endemic
DILLENIACEAE		
Hibbertia saligna	Mt Wilson, Mt Tomah, Wentworth Falls, Springwood	2RC
EPACRIDACEAE		
Epacris apiculata	Rock ledges, Wentworth Falls	3RC
Epacris hamiltonii	Only known from Blackheath	3RC, highly restricted local endemic
Epacris muelleri	Damp rocks, Blackheath Mt Wilson	3RC
Leucopogon sp. aff. *appressus*	Rocky outcrops, Bedford Ridge	Local form
Lissanthe sapida	Blue Mountains	2RC
Rupicola sprengelioides	Blue Mountains	3RC
Sprengelia monticola	Wet rock ledges, upper Blue Mountains	3RC
EUPHORBIACEAE		
Beyeria lasiocarpa	Jenolan River gorge	Local disjunct population
Pseudanthus divaricatissimus	Heath, Narrow Neck & Kings Tableland	3RC

Species (family)	Habitat/Locality	Significance
FABACEAE		
Acacia asparagoides	Glen Davis–Lawson	Local endemic
Acacia baueri ssp. *aspera*	Kings Tableland, Wentworth Falls	Local disjunct population, also near Wilton
Acacia bynoeana	Hazelbrook–Bell	3V
Acacia clunies-rossii	Coxs, Kowmung Rivers, Yerranderie	2V
Acacia hamiltoniana	Bell to Mt Wilson	Uncommon
Acacia ptychoclada	Swamps & creek banks, Woodford to Mt Victoria	Local endemic
Mirbelia baueri	Kings Tableland	Local disjunct population Nth. limit
Pultenaea echinula	Kings Tableland, Mt Victoria, Cyrils Rocks	Local endemic
Pultenaea glabra	Wentworth Falls–Katoomba	3V
Pultenaea incurvata	Wentworth Falls–Clarence	2RC, local endemic
GERANIACEAE		
Geranium graniticola	Kanangra to Oberon	3RC
GOODENIACEAE		
Goodenia rostrivalvis	Lawson to Leura	2RC
Scaevola hookeri	Blackheath	Local population
LORANTHACEAE		
Atkinsonia ligustrina	Linden, Bedford Ck, Mt Wilson, Bilpin	2K
MYRTACEAE		
Darwinia fascicularis ssp. *oligantha*	Mt Banks–Wentworth Falls	Local endemic
Eucalyptus baeuerlenii	Terraces of south-facing clifflines, Wentworth Falls	3RC, local disjunct population Nth. limit
Eucalyptus benthamii	Alluvium, Kedumba Valley	3RC, local endemic
Eucalyptus burgessiana	Ridges, Linden, Mt Tomah	2VC, local endemic
Eucalyptus gregsoniana	Blackheath–Clarence, Budawangs	3V, local disjunct population
Eucalyptus ligustrina	Kings Tableland	Local disjunct population
Eucalyptus macarthurii	Boyd Crossing	3V, local disjunct population, Nth. limit
Eucalyptus moorei	Narrow Neck, Bell	Local disjunct population
Eucalyptus pulverulenta	Mt Blaxland, Lowther Ck.	3V, local disjunct population Nth. limit
Eucalyptus rupicola	Cliff edges, Wentworth Falls–Katoomba	2RC
Kunzea sp. nov.	Amongst rocks, Mt Cookem	Local endemic
Leptospermum sp. nov. 'L'	Heath, woodland, Hassans Walls	2R, local endemic
Leptospermum sp. nov. 'R'	Cliffs, Kings Tableland–Glen Davis	Local population
Leptospermum sp. nov. 'Y'	Mallee heath, Kanangra	Local endemic
Melaleuca armillaris	Jenolan River gorge	Local disjunct population
Melaleuca squamea	Wentworth Falls, Blackheath	Uncommon
PROTEACEAE		
Grevillea obtusifolia	Kedumba Valley, Kiaramba Ridge	3V, local endemic, Rylstone-Kedumba
Grevillea rosmarinifolia	Coxs River, Glenroy Crossing	Type form, now presumed extinct

Species (family)	Habitat/Locality	Significance
Hakea constablei	Kings Tableland, Mt Wilson–Mt Banks	3V, local endemic
Isopogon fletcheri	Found only at Govetts Leap, Blackheath	2VC, highly restricted, local endemic
Persoonia acerosa	Valley Heights–Clarence	Local endemic
RUTACEAE		
Boronia deanei	Swamps, Boyd Plateau	2VC, local pop., also near Newnes & Nerriga
Eriostemon obovalis	Blackheath–Bell	2RC
Zieria sp. nov. 'F'	Narrow Neck	2VC, local endemic
SCROPHULARIACEAE		
Parahebe sp. (Mt Colong)	Kanangra–Mt Colong, McMahons Lookout, on rocky outcrops	2RC, local endemic
MONOCOTYLEDONS		
LILIACEAE		
Allania endlicheri	Gullies on moist rocks, Mt Corricudgy–Linden	3RC
Blandfordia cunninghamii	Wentworth Falls, Mt Tomah	3RC, local population
ORCHIDACEAE		
Adenochilus nortonii	Woodford–Mt Victoria	3V
Prasophyllum ansatum	Mt Wilson–Bell	3RC
POACEAE		
Deyeuxia microseta	Forests, higher altitudes	3V
Notochloe microdon	Swamps, higher altitudes	2RC

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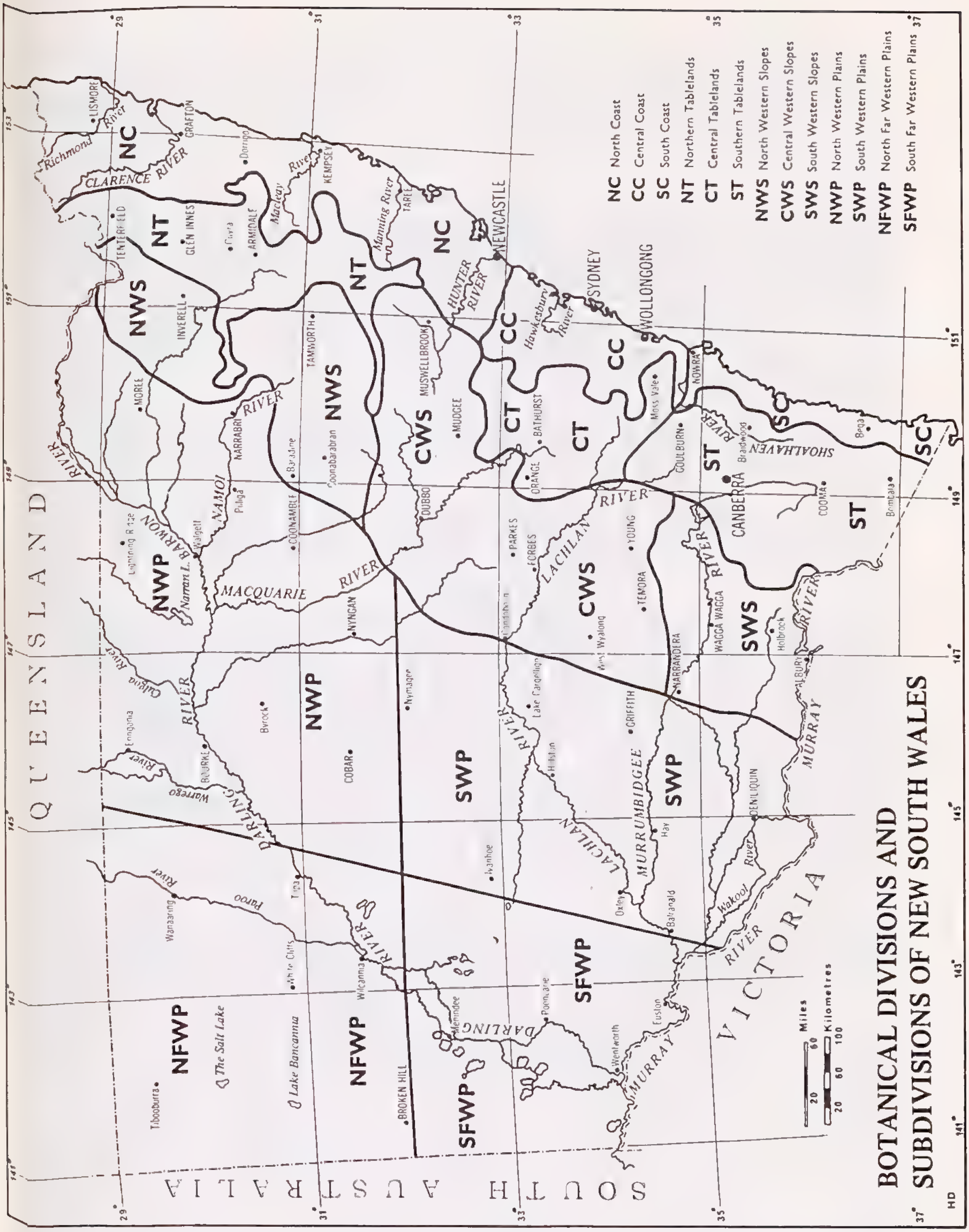

For explanation and description of the Botanical Divisions and Subdivisions of New South Wales see Anderson, R. H. (1961). Introduction. *Contr. New South Wales Natl. Herb. Fl. New South Wales* Nos 1–18, pp. 1–15.

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Manuscripts. Two copies of the manuscript, each accompanied by copies of all illustrations, should be sent to the Editor, *Cunninghamia*, National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, 2000. They should be typed double-spaced on one side only of the paper, with ample margins. Style should follow that of a recent issue. The full postal address of the author who will check the proofs and receive correspondence should be included, as well as the present address of any author if different from that where the work was carried out. All pages should be numbered consecutively. The main title should be explicit and descriptive of the content of the paper; a short running title should also be provided. It would be helpful if authors could indicate in the margin the relative importance of headings by use of ringed capital letters, e.g. (A) for main headings, (B) for secondary headings and (C) for tertiary headings, etc. Footnotes within the text should be used only when essential. They should be placed below a horizontal line at the foot of the page.

Abbreviations, units, etc. SI units (metre, kilogram, etc.) are to be used. Statistics and measurements should always be given in figures, e.g. 10 mm, except where the number begins the sentence. The *Style Manual for Authors, Editors and Printers*, 4th edn, AGPS, 1988, should be consulted for spelling, abbreviations and other conventions.

Tables. The presentation of the same data in both graphical and tabular form should be avoided. Tables must be clearly headed and, if possible, self-explanatory. They must be typed on separate sheets and should be numbered consecutively with arabic numerals. Column headings should be brief with units of measurements in parentheses. Each table must be referred to in the text and its approximate position should be indicated in the margin of the manuscript.

Figures and Illustrations. All illustrations (including photographs) are classified as figures and should be numbered consecutively. Line drawings should be in black ink on stout white paper or strong tracing paper, photographs should be unmounted good quality glossy prints. All original illustrations should be submitted unlettered, with lettering clearly shown on a copy. Figures should be suitable for 30–50% reduction and should be drawn or grouped so that on reduction they will fit within the type area (205 x 125 mm). Bar scales for maps and photographs are preferred to numerical scales. Maps should include all relevant place names and site locations. Preferred symbols are open and closed circles, squares and triangles; the symbols × and + should be avoided. Authors wishing to submit large or complex maps should discuss cartography with the Editor before final preparation.

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The vegetation of Mallee Cliffs National Park

L. Morcom and M. Westbrooke

Abstract

Morcom[1], L. and M. Westbrooke[2] ([1]Department of Conservation and Environment, Horsham, Australia, 3400; [2]Department of Applied Biology, Ballarat University College, Ballarat, Australia 3350) 1990. The vegetation of Mallee Cliffs National Park. Cunninghamia 2(2): 147–166. The vegetation of Mallee Cliffs National Park, in semi-arid south-western New South Wales, was mapped at 1:50 000 using aerial photographs, landsat imagery and extensive ground truthing. The communities were assessed using a quadrat sampling technique. The data from 92 quadrats were analysed via a computer-based numerical sorting and classification procedure to determine the floristic composition of the communities. The most widespread communities are *Eucalyptus gracilis/E. dumosa/E. socialis* open scrub and *Casuarina cristata* subsp. *pauper* woodland. Small areas of *E. largiflorens* and *Acacia aneura* open-woodlands occur, as well as open-herblands, deduced to be either degraded examples of the above communities or of *Callitris glaucophylla* low woodland, *Maireana pyramidata* low open-shrubland or *M. sedifolia* low open-shrubland.

A total of 215 species including 43 exotics were recorded from 50 families.

Introduction

A comprehensive study of the vegetation of south-western New South Wales was carried out by Beadle (1948) who also produced a vegetation map at 1:1 000 000 (Beadle 1945). Subsequently little systematic vegetation survey has been carried out in the area although the National Herbarium is currently surveying and mapping the vegetation with the aim of producing maps at 1:250 000 (Fox 1983). Other studies in the area have included a multi-variate analysis of the vegetation of a large area of semi-arid south-eastern Australia (Noy-Meir 1971) and a study of the effects of fire in *Eucalyptus* open-scrub to the north and east of Mallee Cliffs National Park (Noble, Smith and Leslie 1980). A preliminary checklist of the flora of the Park has been prepared by the Soil Conservation Service (Semple unpublished).

The aim of this study was to expand the limited knowledge of the vegetation of the Park and to thus provide a basis for future management.

The Study Area

Mallee Cliffs National Park, 30 km east of Wentworth, (Figure 1) covers 57,969 ha. It was established in 1977 on the site of the former Mallee Cliffs Station, to conserve an example of mallee vegetation in south-western New South Wales. South-western New South Wales has been grazed by sheep and cattle for over 100 years and the Park is presently surrounded by pastoral properties. Most of the Park was burnt in the extensive wildfires of 1974/75 (Pickard 1987). Sheep were removed from the Park in 1977 but significant numbers of goats, rabbits and kangaroos maintain high grazing pressure. Past grazing and timber cutting has degraded some sections of the Park, particularly around the 18 earth tanks.

In the years prior to 1977, Mallee Cliffs Station was managed by a Pastoral Company. In the 20 years to 1977, with the lease soon to expire, the station was stocked at maximum capacity (Palmer, R. pers. comm.). This varied according to season from 4000 to 8500 sheep, being within the limits judged by Stanley and Lawrie (1980) as reasonable for the area. The limiting factor to stocking was water rather than feed, resulting in high grazing pressure adjacent to the tanks. The highest stocking rates were in the south around Bulbuc Tank and in the east, adjacent to Gulthal Station (Palmer, R. pers. comm.). The area around Mulga Tank was rarely stocked because of the dense vegetation and lack of water, since Mulga Tank did not hold water. The extensive area of *Eucalyptus* open scrub with *Triodia* understorey, east of Chalky Tank, was not utilised (Ablett, R. pers. comm.).

Climate

The climate is classified as cool semi-arid (Dick 1975). Yearly variation in rainfall is high, Wentworth having a long term average of 289 mm, but over the past 115 years the annual rainfall has ranged from 115 mm to 705 mm (Bureau of Meteorology records 1987). Temperatures range from a mean daily maximum in January of 33.2° C. to a mean daily minimum in July of 4.5° C. Frosts are common in the winter months.

Topography, geology and soils

The area lies in the Murray Basin geological province and consists of Quaternary material with virtually no rock outcropping. Low aeolian dunes and

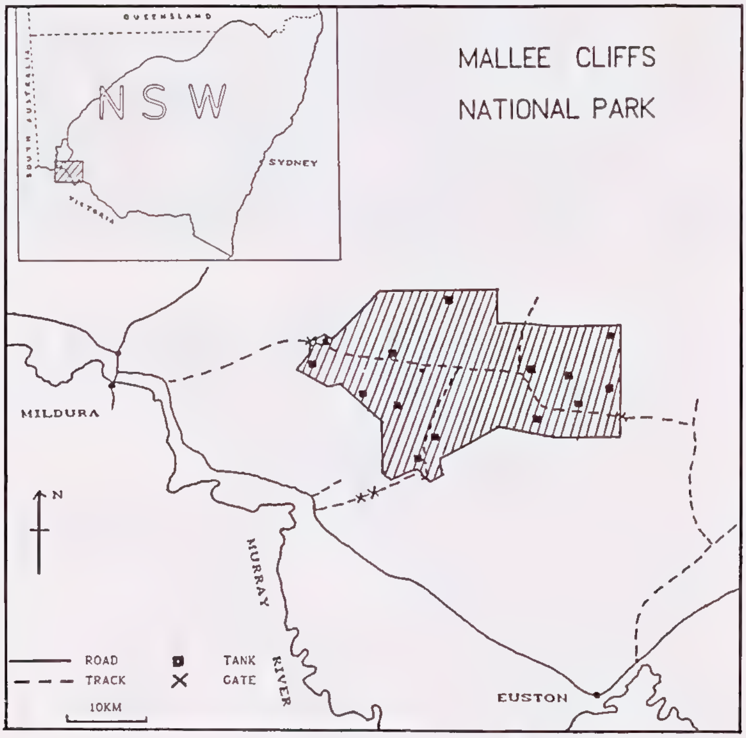


Figure 1. Location and access – Mallee Cliffs National Park

alluvial plains predominate in the landscape. Calcareous plains of loam or sandy loam solonized brown soils, often with limestone nodules at the surface, alternate with an irregular system of low east-west dunes of red earthy sands and sandy solonized brown soils overlying sandy clays (Lawrie and Stanley, 1980).

Methods

During studies in 1983, 1985, 1987 and 1989, ground truthing was undertaken by driven (90 km) and walked transects (270 km). Information from these transects was used in conjunction with study of black and white aerial photographs (Department of Lands Wild Dog and Mildura 1:110 000, flown in 1973, 1974 and 1979) and a Landsat false colour image to produce a vegetation map at 1:50 000. The vegetation communities mapped were defined by floristic and structural characteristics (Specht 1970).

Ninety-two 0.01 ha (10 m x 10 m) quadrats were sampled and all species occurring were recorded, together with a cover abundance value for each species modified from Braun-Blanquet (1928) which corresponded to a visual estimate of its performance in the quadrat. Quadrats were subjectively located following the method of Gullan et al. (1979). This method ensured that all communities were sampled and provided data on floristic variability within the communities. Communities were in general sampled in proportion to the area they covered, however, since quadrats were located along transects wherever community type was observed to change, those with a discontinuous distribution may tend to be over-sampled. The floristic data were analysed using a computer-based numerical classification procedure coupled with a hand sorting procedure of the type outlined in Gullan (1978). The final result of this analysis is a two way table that holds data in a sorted form. Quadrats of similar floristic composition are grouped on the horizontal axis of the table while species that tend to occur together are grouped on the vertical axis (Appendix 1). All vascular plant species recorded over the four visits, both from sampled quadrats and from opportunistic collection, were identified and a species list compiled (Appendix 2). For each quadrat the number of exotic species as a proportion of the total number of species was calculated and used to determine the mean '% weediness' of each community. The mean species richness of quadrats in each community was also calculated.

Vegetation

The vegetation of the Park consists predominantly of *Eucalyptus gracilis/E. dumosa/E. socialis* open scrub and *Casuarina cristata* subsp. *pauper* woodland, but ten distinct communities were recognised (Figure 2). Several of these communities are, however, of limited occurrence. The communities in the Park are:

Community	**% area**
1 *Eucalyptus gracilis/E. dumosa/E. socialis* open-scrub	60
2 *Eucalyptus gracilis/E. dumosa/E. socialis* open-scrub, *(Triodia* understorey)	16

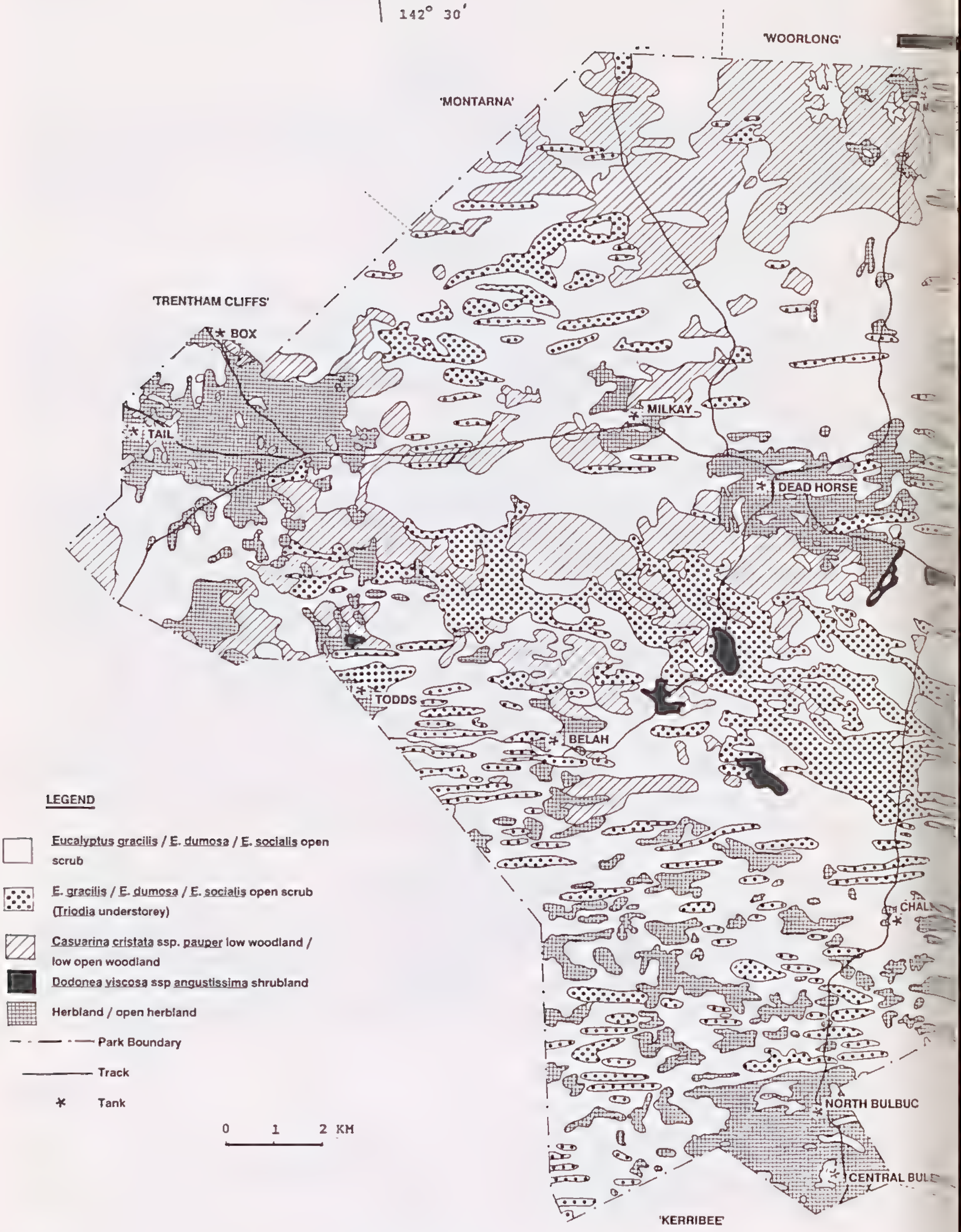
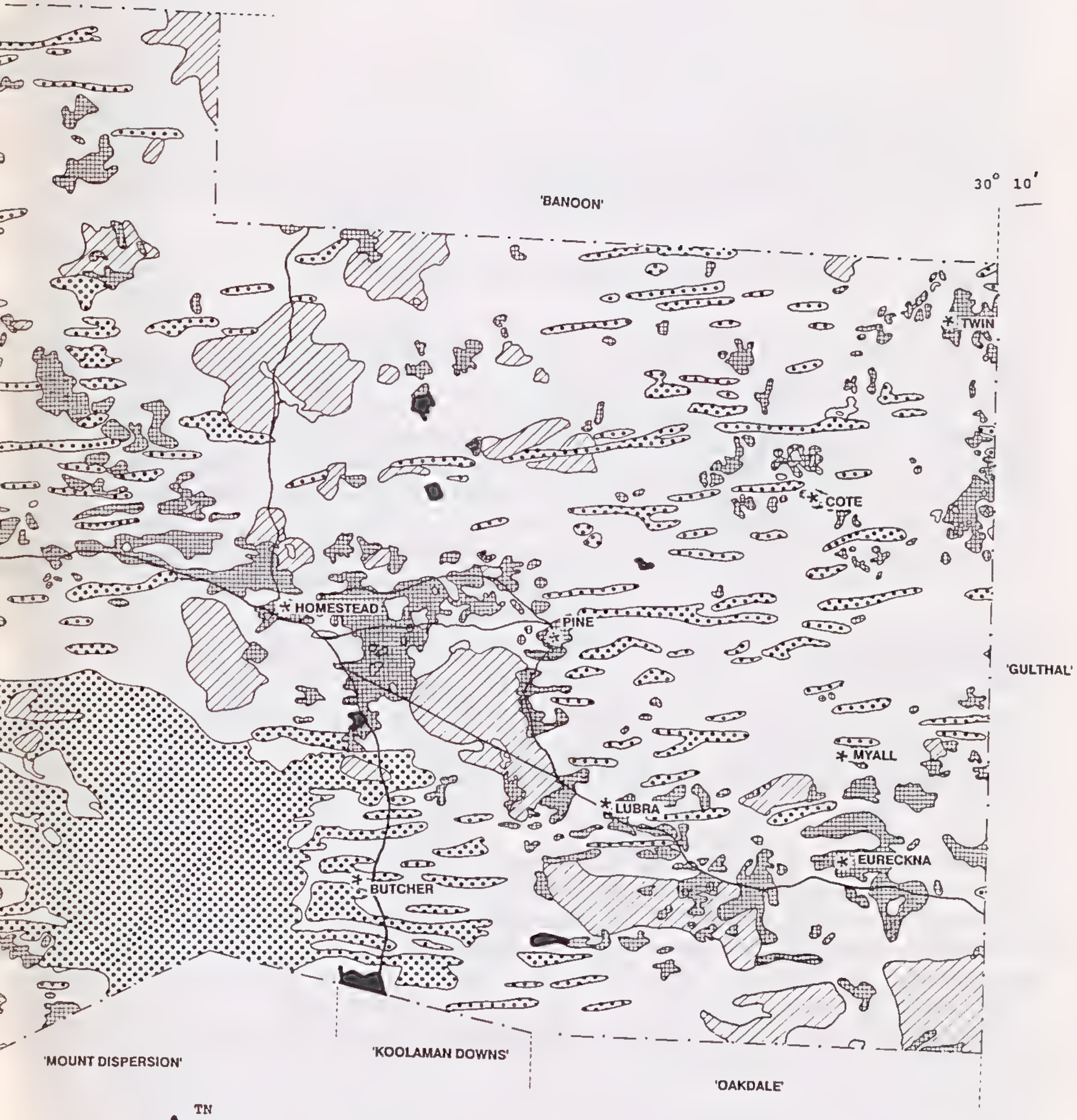

142° 30′
'WOORLONG'
'MONTARNA'
'TRENTHAM CLIFFS'
BOX
TAIL
MILKAY
DEAD HORSE
TODDS
BELAH
CHAL
NORTH BULBUC
CENTRAL BUL
'KERRIBEE'
LEGEND
Eucalyptus gracilis / E. dumosa / E. socialis open scrub
E. gracilis / E. dumosa / E. socialis open scrub (Triodia understorey)
Casuarina cristata ssp. pauper low woodland / low open woodland
Dodonea viscosa ssp angustissima shrubland
Herbland / open herbland
Park Boundary
Track
Tank
0 1 2 KM

Figure 2. Vegetation of Mallee Cliffs National Park



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Ballarat C. A. E. 1989

3	*Casuarina cristata* subsp. *pauper* low woodland/low open-woodland	13
4	*Callitris glaucophylla* low open-woodland	< 1
5	*Eucalyptus largiflorens* open-woodland	< 1
6	*Acacia aneura* open-woodland	< 1
7	*Dodonaea viscosa* subsp. *angustissima* shrubland	< 1
8	*Maireana sedifolia* low open-shrubland	< 1
9	*Maireana pyramidata* low open-shrubland	< 1
10	Herbland/open-herbland	10

Appendix 1 details the floristic composition of each community. The descriptions below summarise the table and provide additional information concerning less common species.

1. *Eucalyptus gracilis/E. dumosa/E. socialis* open-scrub (Figure 3)

The most extensive community (60% of the area) within the Park is *Eucalyptus* open-scrub dominated by *E. gracilis, E. dumosa* and *E. socialis*, growing to eight metres on interdune plains of sandy-loam solonised soils. *E. leptophylla* and *E. oleosa* occur less frequently. Common shrub associates include *Cassia eremophila, Dodonaea viscosa* subsp. *angustissima, Zygophyllum* spp., *Westringia rigida, Eremophila glabra, Chenopodium curvispicatum* and *Grevillea huegelii.* In localised situations other species may also be prominent in the understorey. These include *Lomandra leucocephala* subsp. *robusta, Acacia microcarpa* and *Maireana pentatropis.* Exotic species occur infrequently in both this and the *Eucalyptus* open-scrub community described below.

2. *Eucalyptus gracilis/E. dumosa/E. socialis* open-scrub with *Triodia* understorey (Figure 4)

On low dune ridges where shallow sands overlie sandy clays the eucalypts noted above occur in a community characterised by the presence of *Triodia scariosa* as the most prominent component of the understorey. This community occupies 16% of the Park. Shrub associates include *D. viscosa* subsp. *angustissima, E. glabra, Myoporum platycarpum* and *C. eremophila. Baeckea crassifolia, Acacia wilhelmiana, A. microcarpa* and *Pittosporum phillyraeoides* may be locally common. Several species are restricted to this community including *Eucalyptus incrassata, B. crassifolia* and *Exocarpos sparteus* — the latter two species are recorded only occasionally in New South Wales (Cunningham et al. 1981).

3. *Casuarina cristata* subsp. *pauper* low woodland/low open-woodland (Figure 5)

Casuarina cristata subsp. *pauper* growing to 10–12 metres, occurs as a dominant over 13% of the Park on the brown loamy sands of interdune areas. It is usually associated with *Alectryon oleifolius* subsp. *canescens* although pure dense stands of either species occur. Common understorey associates include *Olearia muelleri, Zygophyllum apiculatum, Atriplex vesicaria, Exocarpos aphyllus* and *Actinobole uliginosum.* On occasions *D. viscosa* subsp. *angustissima, Cassia eremophila, Myoporum platycarpum, Acacia colletioides* and *Maireana pyramidata* may dominate the understorey.

In the north-east of the Park *Geijera parviflora* is an occasional associate in this community. The low dense canopy of *G. parviflora* provides shelter for a number of species, including *Parietaria debilis*, not previously recorded in the South Far Western Plains (SFWP), (Jacobs and Pickard 1981; Jacobs and Lapinpuro 1986).

4. ***Callitris glaucophylla*** **low open-woodland** (Figure 6)

Within *Casuarina cristata* subsp. *pauper* woodlands *Callitris glaucophylla* growing to ten metres, occurs as scattered individuals and is the dominant in a few small areas. The presence of senescent specimens of *C. glaucophylla* in the herblands suggests that *C. glaucophylla* may have been more extensive prior to pastoral activity. Existing *C. glaucophylla* woodland carries an open understorey largely consisting of exotic herbs and grasses. The exotic *Psilocaulon tenue* and the natives *Enchylaena tomentosa* and *Dissocarpus paradoxus* are also common in the understorey.

5. ***Eucalyptus largiflorens*** **open woodland** (Figure 7)

A small patch of *E. largiflorens* open woodland growing to ten metres occurs on heavy soil in the north-western corner of the Park adjacent to Box Tank. The understorey consists largely of exotic herbs and grasses. Species present include *Carrichtera annua, Hordeum leporinum, Schismus barbatus* and *Lophochloa pumila.*

6. ***Acacia aneura*** **open woodland** (Figure 8)

In the north of the Park adjacent to Mulga Tank is a patch of *A. aneura* open woodland growing to twelve metres. The patch is surrounded by *Casuarina cristata* subsp. *pauper* woodland. The understorey is dominated by species associated with the herblands. Notable in this community was the one record of *Cheilanthes austrotenuifolia* and the occurrence of *Papaver hybridum*, an exotic not previously recorded from the SFWP (Jacobs and Pickard 1981; Jacobs and Lapinpuro 1986).

7. ***Dodonaea viscosa*** **subsp.** ***angustissima*** **shrubland** (Figure 9)

In a number of sites, *D. viscosa* subsp. *angustissima* forms dense stands to approximately two metres. *D. viscosa* subsp. *angustissima* is also found as a common understorey component of the *Eucalyptus* open scrubs. Boomsma and Lewis (1980) note that *Dodonaea* spp. have effective and continuous regeneration from seed. Noble (1984) and Harrington et al. (1984) report an increase of *Dodonaea* spp. in response to grazing and Beadle (1948) reports that the genus is an early coloniser following clearing of mallee for agriculture. It thus seems likely that this community results from past land use, particularly clearing of *Eucalyptus* open scrub.

8. ***Maireana sedifolia*** **low open-shrubland** (Figure 10)

Two small areas of low open shrubland dominated by *M. sedifolia* growing to 1.5 metres occur in the Park. Both are on soils with a high clay content and,

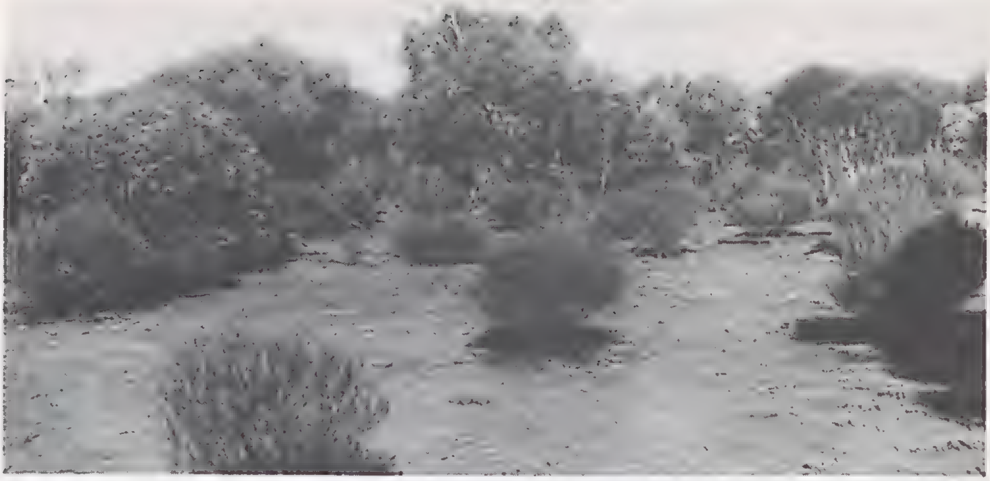

Figure 3. *Eucalyptus gracilis/E. dumosa/E. socialis* open-scrub

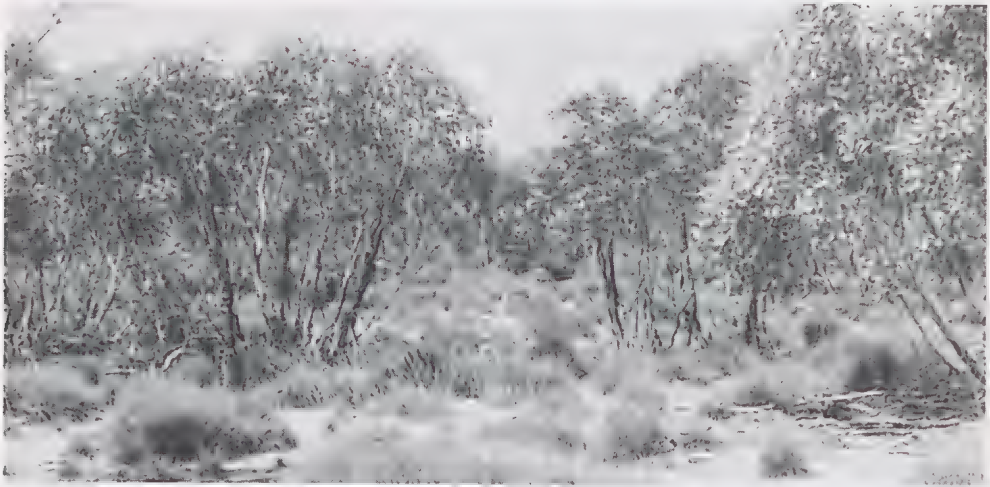

Figure 4. *Eucalyptus gracilis/E. dumosa/E. socialis* open-scrub with *Triodia* understorey

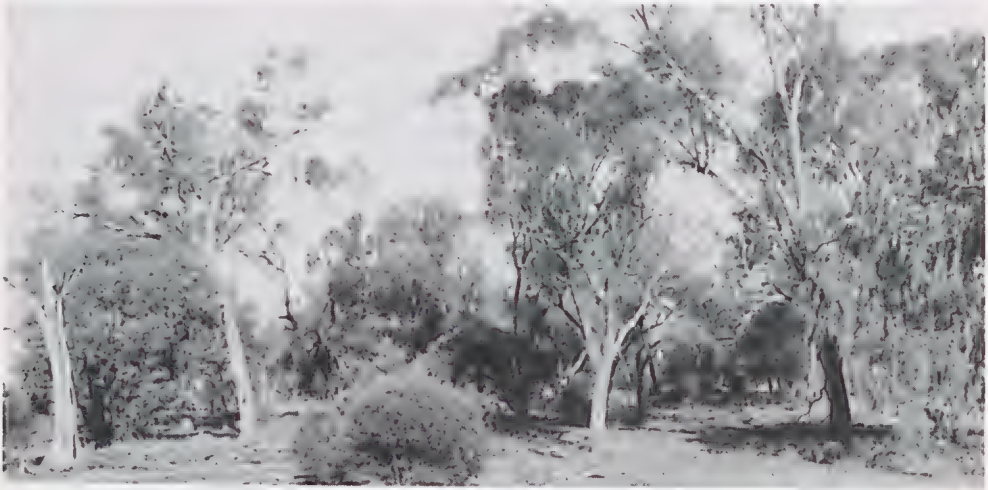

Figure 5. *Casuarina cristata* subsp. *pauper* low woodland/low open-woodland

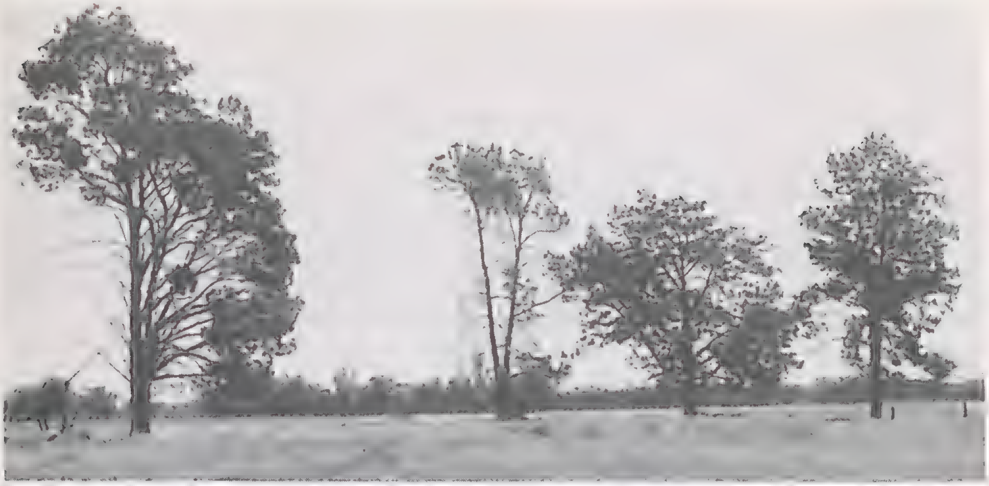

Figure 6. *Callitris glaucophylla* low open-woodland

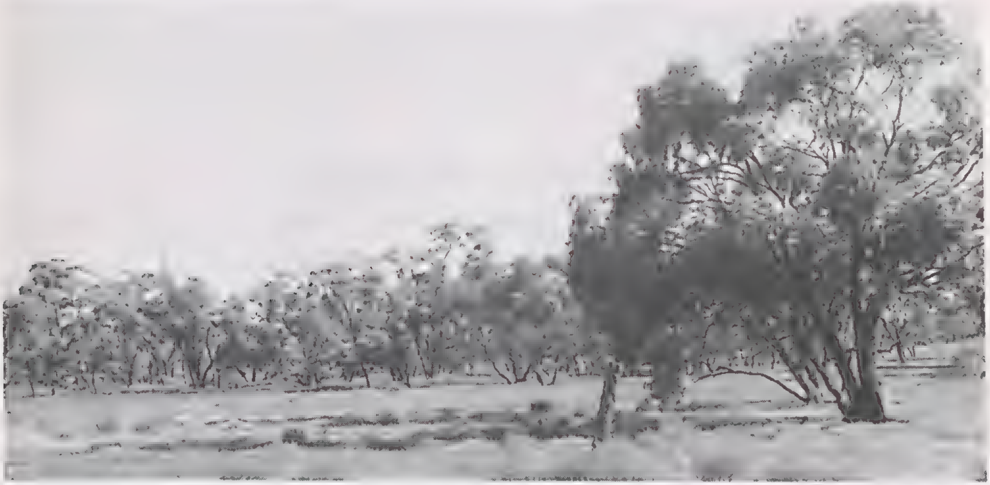

Figure 7. *Eucalyptus largiflorens* open-woodland

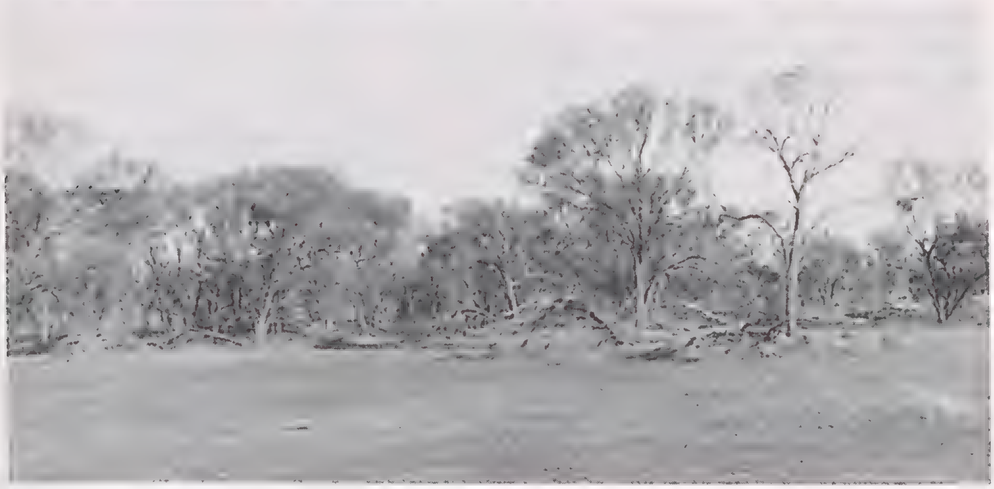

Figure 8. *Acacia aneura* open-woodland

following heavy rain, ephemeral pools of water occur on these areas. Associated species are restricted to native and exotic annuals.

9. *Maireana pyramidata* low open-shrubland (Figure 11)

Small areas of low open shrubland dominated by *M. pyramidata* growing to one metre also occur on heavy soils. Associated species are restricted to annual herbs and grasses and a few chenopod species. Both *M. pyramidata* and *M. sedifolia* are palatable to stock (Cunningham et al. 1981) and Noble (1984) notes that *M. sedifolia* decreases in response to grazing. It seems likely that both *Maireana* species were once more common in the Park.

10. Herbland/open-herbland (Figure 12)

Extensive herbland/open herbland growing to 0.8 metres occurs, consisting largely of annual herbs and grasses, many of which are exotic. Common species in this community include *Bromus rubens, Psilocaulon tenue, Erodium* spp., *Scleroleana obliquicuspis, Salvia verbenaca, Hordeum leporinum, Medicago* spp., *Omphalolappula concava* and *Sisymbrium irio.* The relative dominance of species varies dramatically with seasonal conditions, with the extent and seasonal distribution of rainfall being critical in determining relative species abundance.

Distribution of communities

The distribution of communities is shown on the Vegetation map of Mallee Cliffs National Park (Figure 2).

The species

The species list includes 213 species from 50 families. This number includes 42 exotics, most of which are pasture species or weeds commonly associated with agriculture. The *Eucalyptus* open scrub communities are relatively free of weeds. The 'weediness' and species richness of each community is shown on Table 1.

Table 1. Mean species richness and percentage weediness of plant communities at Mallee Cliffs National Park.

	No. of quadrats	Mean species richness	mean % weediness
Eucalyptus gracilis/E. dumosa/E. socialis open-scrub	43	11	3
E. gracilis/E. dumosa/E. socialis open-scrub *(Triodia)*	23	11	5
Casuarina cristata subsp. *pauper* low woodland/low open-woodland	10	15	11
Dodonaea viscosa subsp. *angustissima* shrubland	2	21	25
Acacia aneura open-woodland	1	16	25
Callitris glaucophylla low open-woodland	1	22	32
E. largiflorens open-woodland	1	31	33
Maireana sedifolia low open-shrubland	2	19	35

	No. of quadrats	Mean species richness	mean % weediness
M. pyramidata low open-shrubland	2	14	50
Herbland/open-herbland	7	11	56

Voucher specimens are held at the Department of Applied Biology, Ballarat C.A.E. Species not previously recorded for the SFWP were forwarded to the National Herbarium, Sydney, for verification.,

Discussion

The distribution and species composition of plant communities within Mallee Cliffs National Park is largely determined by minor changes in topography and associated soil type. *Eucalyptus* open-scrub with a *Trodia scariosa* understorey is associated with sandy soils on the low dunes. *Eucalyptus* open-scrub with a shrub understorey occurs on the sandy loam, solonised brown soils of the calcareous sandplains. *Casuarina cristata* subsp. *pauper* woodlands and *Maireana* spp. shrublands occur on calcareous plains of loamy solonised brown soils. A number of other factors, notably fire and past grazing history, have also played a role in determining the present distribution and floristic composition of the communities present.

Eucalyptus open-scrub communities are highly flammable and most of those in the Park were burnt in the extensive wildfires of 1974/75 (Pickard 1987). However dense stands of *C. cristata* subsp. *pauper* did not burn in this fire (Ablett pers. comm.). Fire leads to an increase in certain species such as *Halgania cyanea, Exocarpos sparteus, Haloragis odontocarpa* and *Codonocarpus cotonifolius* but these species decline as *Triodia* hummocks redevelop (Noble and Mulham 1980).

The Park is at the stage of post fire succession where fire-promoted species decline.

The pastoral history of Mallee Cliffs Station is reflected in the degraded nature of the *Eucalyptus* open scrub around Bulbuc Tank. Dense stands of *Nitraria billardieri* found around several tanks in the east of the Park may also be an indicator of heavy grazing in the past; an effect noted by Cunningham et al. (1981).

In some of the herblands small patches of *Callitris glaucophylla* low open-woodland occur. It is likely that these woodlands were once more extensive, but fire, harvesting of timber and grazing of seedlings by stock and rabbits have resulted in the decline of this community.

The most obvious effect of past grazing is the existence of herblands. These are generally associated with the 18 earth tanks, sites for which are limited to areas of occluded drainage and associated texture-contrast soils for catchment (Condon 1980). It thus appears likely that the herblands originally carried communities which, within the Park, are associated with heavy soils, i.e. chenopod shrublands or arid woodlands. Rabbits, goats and high kangaroo populations, partially sustained by permanent water in tanks, maintain grazing pressure on the herblands, possibly limiting recovery of the original communities (presumed to include *Maireana* spp. low open-shrublands and arid woodlands).

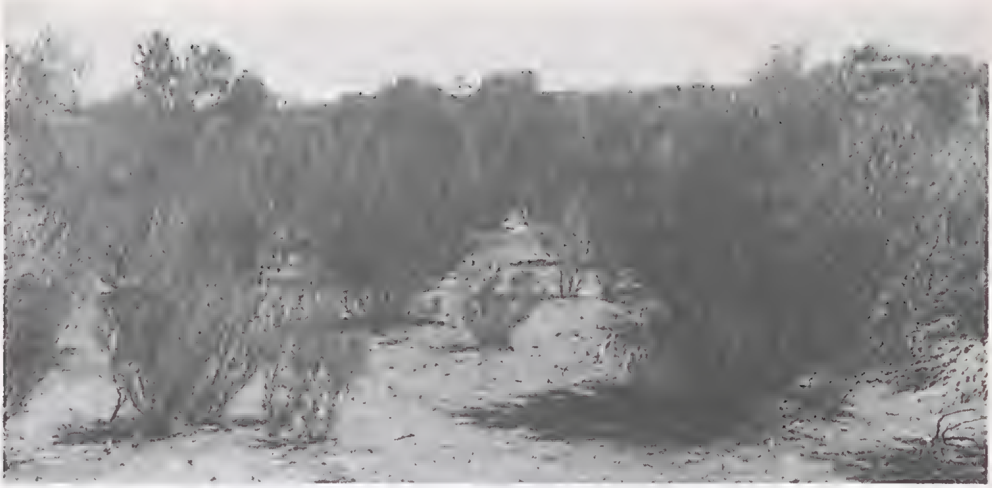

Figure 9. *Dodenaea viscosa* subsp. *angustissima* shrubland

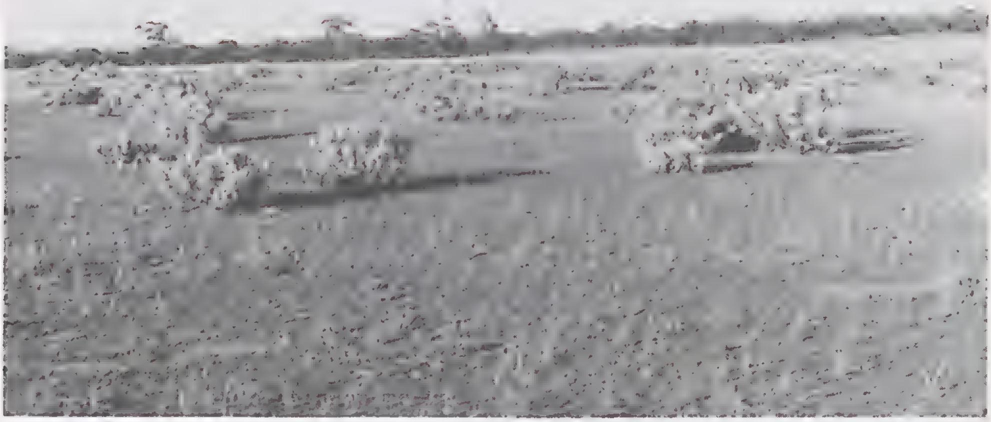

Figure 10. *Maireana sedifolia* low open-shrubland

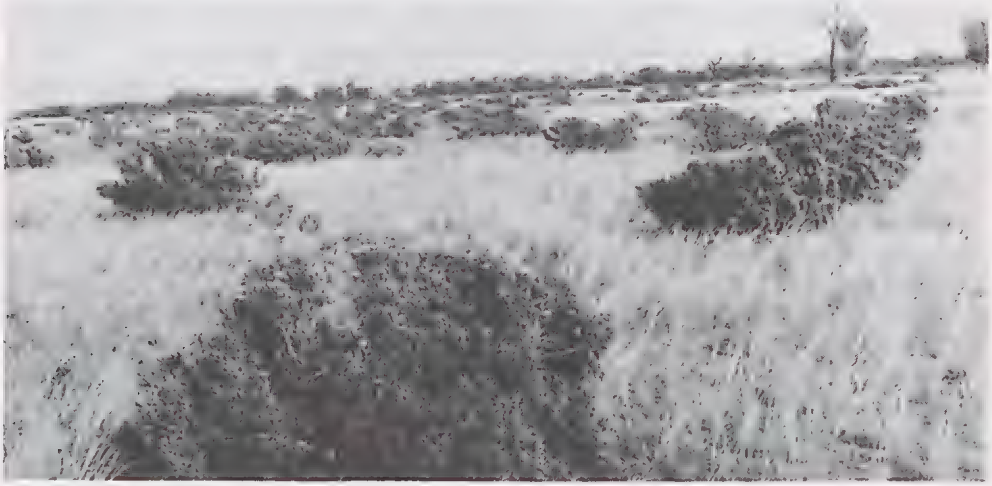

Figure 11. *Maireana* low open-shrubland

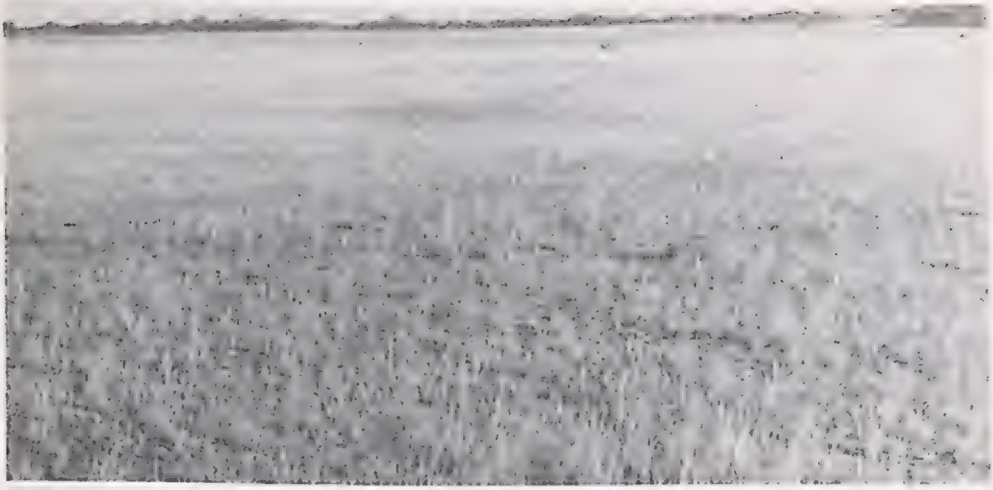

Figure 12. Herbland/open-herbland

The earth tanks and their associated channels support areas that remain wetter or receive greater run-off than would be the case in an unmodified environment. This factor, together with the disturbance caused by clearing and grazing, has contributed to the relative weediness of the herblands. Exotics recorded in the herbland but not previously recorded for the SFWP are *Arctotheca calendula, Echium plantagineum, Medicago laciniata, Malva parviflora, Oxalis pes-caprae* and *Sisymbrium orientale* (Jacobs and Pickard 1981; Jacobs and Lapinpuro 1986). Native species present in the herbland not recorded by the above authors are *Iseotopsis graminifolia,* a common component of the herbland, and *Limosella curdieana* found growing near Cote Tank.

A further three native species not previously recorded from the SFWP (Jacobs and Pickard 1981; Jacobs and Lapinpuro 1986) were found in the Park — *Maireana trichoptera, Ptilotus spathulatus* and *Zygophyllum billardieri.*

Conclusion

Mallee Cliffs National Park contains extensive areas of three vegetation communities. Small areas of five other natural communities add diversity. The herblands and the *Dodonaea viscosa* subsp. *angustissima* shrublands are regarded as artificial communities. Many areas of the Park show clear evidence of past grazing pressure in the form of limited understorey and high weediness while those areas that were not heavily grazed remain relatively intact. It seems unlikely that rapid recovery will occur in degraded areas unless continued high grazing pressure from kangaroo populations, rabbits and feral goats is reduced. Closure of earth tanks together with intensive rabbit control are the most appropriate strategies to assist recovery.

Acknowledgements

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Appendix 1

Two-way table presenting data on species and communities at Mallee Cliffs National Park

* denotes exotic species

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Appendix 1
        TWO-WAY TABLE PRESENTING DATA ON SPECIES AND COMMUNITIES AT MALLEE CLIFFS NATIONAL PARK
• denotes exotic species
   Community code          |S|8 |9 |  10   |          2           |                     1                      |7 | |4|     3     |
            Quadrat Numbers|0|02|53|1022564|6631243165301356515300|67777777777888888888899995420136554121236244|04|1|2|34664351140|
Species                    |3|68|65|1507788|0376243348670902475229|901234567890123456789012323858121791864655 3|49|3|4|16570092411|
 Eucalyptus largiflorens   |2|  |  |       |                      |                                           1|  | |1|           |
•Medicago laciniata        |1|1 |  |       |                      |                                            |  | | |           |
 Maireana sedifolia        | |21|+ |       |                      |                                            |  | | |        2  |
 Maireana pyramidata       | |  |1+|+      |                      |                                            |  | | |           |
•Sisymbrium orientale      | |  |11|2      |                      |                                           +|  | | |    +    + |
 Erodium cicutarium        | |+ |1+|      1|                      |                                            |  | | |           |
•Alyssum linifolium        | |+ |1 |1++    |       +    +       + |                                            |  | |1|         + |
•Carrichtera annua         |2|  |  | 12    |                    + |            1         12        +      +   +|  | | |           |
•Bromus rubens             | |+ | 2|+3 113 |                      |                                            |1 | |+|           |
•Salvia verbenaca          |1|++|+1|+++ 11+|                      |                     ++                     |+ |+|+|           |
•Medicago minima           |+|1 |33|31 3333| 1         +        1 |                                            |12|1| |         +1|
•Hordeum leporinum         |2|++|21|3+1 23 |            +         |                                            |  |+|2|          +|
 Omphalolappula concava    |+|11|11|   +++1|           ++       1 |                                           1|1 |+|1|         1+|
 Sclerolaena obliquicuspis | |  |+1|+++  2 |++      ++            |11  +11  111111+   1  111       +1  +   +21+|11| | |++   +     |
•Sisymbrium irio           |1|  |++|+++    |             +        |      +   1   121 +111+1          +1+       |  |1|1|+    +11++1|
 Triodia scariosa          | |  |  |       |  3232232232233323+122|                                            |  | | |         + |
 Eucalyptus gracilis       | |  |  |       |2+2+22+22222 322212 21|11111+ 21    1   1 1 111122222 32222+1 12  1|  | | |           |
 Dodonaea viscosa ssp. ang.| |  |  |       |222+1++1   +1 2 +++1 +|1111   + ++ 1  1  +   1 1 1 + +1  +++      3|4 |+| |   +  2+   |
 Eucalyptus dumosa         | |  |  |2      |    2222     1  +121  |+11 +1++111111111111111          + 2+11  2 +|  | | |           |
 Eucalyptus socialis       | |  |  |2      |         22112222 + 12|1 111 1+1 11211 1 1   1 111 1 + 2+1  1    1 |  | | |           |
 Eremophila glabra         | |  |  |       | 1 +      2     1+1+++| 1+1   +11111+  +11     +1+ 1+++1+ 1 111  ++|  | | |  +  ++    |
 Cassia eremophila         | |  |  |      1|               2+11 ++|+2 1+  11++121  211   2 13+2 +1+   1 1111 ++|  | |+| 13     + 1|
 Chenopodium curvispicatum | |+ |  |+ 1    |            +++     ++|   +11++  +1  1 1111 1111+++    ++23+       | 1| | | +  + ++++ |
 Myoporum platycarpum      | |  |  |       |       2++ +1121+  111| 1 1 1    + +11 1 1   1 +1     +        +2  | 1| | | 12     1 2|
 Olearia muelleri          | |  |  |       |             +  +++ 1 |+1  +  +         11      + ++        +      |  | | | 2 ++  1+ 1|
 Zygophyllum apiculatum    | |  |  |       |        +           1+|   +  +++111 11111+1 1111 + 1+1+   ++ ++ 1+ |  | | |   1 ++ 1+ |
 Atriplex vesicaria        |+|+ |  |      1|                    + |      121111111+   1+1  1       ++      ++++| 1| | | ++ 1+1   1|
 Maireana pentatropis      | |  |  |       |                 + +  |11 +   1 1 1111 11  +1111 ++      + 2      +|  | | |          1|
 Enchylaena tomentosa      |1|  |  |       |             +   +    |+ +1+ 1+11+1 1111  111111         +        +|  |1|3|         11|
 Salsola kali              |+|+ |  | 1     |                      |   1  1  11  1+1   121111                   |  | | |           |
 Acacia colletioides       | |  |  |       |                + +   |+++++ +    ++     +         ++ +     +      |  |+| |   2+   + +|
 Stipa variabilis          | |  |  |       |                      |1     1  +1+ + + +  +111+                   |  | | |           |
 Westringia rigida         | |  |  |       |       +  ++        ++|  1 +  +1                1+ 22+ +       1  +|  | | | +         |
 Actinobole uliginosum     | |  |  |       |1  +   + +      +     |                                            |+ |1| |1 +21    1+|
 Grevillea huegelii        | |  |  |       |                ++   +|  + +         +   +       +1  + ++  +       |  | | |           |
 Casuarina cristata ssp. p | |  |  |       |                      |                                            |  |+| |22332232222|
 Alectryon oleifolius ssp. | |  |  |       |                      |          1                                 |  | |+|1  2++ 22 1|
 Exocarpus aphyllus        | |  |  |       |                      |                                            |  | | | 1  ++  ++ |
 Erodium crinitum          |+|+ |  | +     |           +         +|                             +              |+ | | |  1        |
•Psilocaulon tenue         | |  |  |1   12 |                      |                   1                        | 2| |3|         1 |
•Carthamnus lanatus        |+|  |  |++     |                      |                                            |  | | |           |
 Senecio glossanthus       |+| +|  |    ++ |+      1   1+   ++  + |                            +              1|1 | | |     + + ++|
•Hypochoeris glabra        |+|+ |  | +  +  |           +        + |                                            |+ | | |       + ++|
 Goodenia pusilliflora     | |2+|  | 1     |   +                  |                                        +  1|+1| | |    +  +   |
•Sonchus oleraceus         |+|+ |  |       |           +        + |                                            |+ | | |          +|
 Baekea crassifolia        | |  |  |       |   22     1           |                                            |  | | |           |
 Acacia wilhelmiana        | |  |  |       |    23         22     |                                            |  | | |           |
 Brachycome sp.            |+|+ |  |   ++  | +          +       + |                                           +|+ | | |    1    ++|
 Lomandra leucocephala     | |  |  |       |     +              + |  +                           +         2   |  | | |  +        |
 Acacia microcarpa         | |  |  |       |+         2           |                            22    +         |  | | |           |
 Eucalyptus leptophylla    | |  |  |       |  2              1    |                         2  2   1           |  | | |           |
 Tetragonia tetragonioides | |  | +|       |                      |                                        +  +|  |+| |  +      + |
 Sclerolaena diacantha     | |  |  |       |           +++      + |                                ++          |  | | |    +      |
 Einadia nutans            | |  |  |       |            ++   +    |                                  ++        |  | | |    1      |
 Dissocarpus paradoxus     | |  |+ |     2 |                      |              +    +++                      |  | |1|  +   +    |
 Zygophyllum iodocarpum    |+|+ |  |       |                    + |                               1++          | 1| | |     +  1 1|
 Zygophyllum aurantiacum   | |  |  |       |                    + |                        1      1+1++     +  |+ | |+|         + |
 Pittosporum phillyreoides | |  |  |     2 |+                +    |         1            1           1+        |  | | |         1 |
 Maireana radiata          | |  |  |       |                      |                        +1         +        |  | | |+   +      |
 Eucalyptus oleosa         | |  |  |       | 1                 +  |             1       +                   22 |  | | |           |
 Olearia pimelioides       | |  |  |       |                  +   |          ++             +            +  ++1|  | | |    +  ++  |
 Amyema preissii           | |  |  |       |                      |                                            |  |+| |    +    + |
 Acacia aneura             | |  |  |       |                      |                                            |  |1| |           |
 Callitris glaucophylla    | |  |  |       |                      |                                            |  | |1|+          |
 Geijera parviflora        | |  |  |       |                      |                                            |  | | |1          |
```

Appendix 2

List of vascular plant species recorded from Mallee Cliffs National Park

Taxonomy according to Forbes and Ross (1988).

* Denotes exotic species.

PTERIDOPHYTA

ADIANTACEAE
Cheilanthes austrotenuifolia

MARSILEACEAE
Marsilea drummondii

GYMNOSPERMAE

CUPRESSACEAE
Callitris glaucophylla

MAGNOLIOPHYTA

LILIOPSIDA
LILIACEAE
* *Asphodelus fistulosus*
Hypoxis glabella var. *glabella*

POACEAE
* *Bromus rubens*
Eragrostis sp.
* *Hordeum leporinum*
* *Lophochloa pumila*
Stipa spp.
* *Schismus barbatus*
Triodia scariosa

XANTHORRHOEACEAE
Lomandra leucocephala
subsp. *robusta*

MAGNOLIOPSIDA

AIZOACEAE
Disphyma crassifolium
* *Psilocaulon tenue*
Tetragonia tetragonoides

AMARANTHACEAE
Alternanthera denticulata
Ptilotus exaltatus
var. *exaltatus*
Ptilotus nobilis
Ptilotus spathulatus

APIACEAE
Daucus glochidiatus

ASCLEPIADACEAE
Leichhardtia australis

ASTERACEAE
Actinobole uliginosum
Angianthus tomentosus
* *Arctotheca calendula*
Brachycome ciliaris
Brachycome melanocarpa
Brachycome lineariloba
Brachycome sp.
Calotis hispidula
* *Carthamus lanatus*
Cassinia arcuata
* *Centaurea melitensis*
Centipeda sp.
Craspedia pleiocephala
Gnaphalium luteo-album
Helichrysum bracteatum
Helipterum floribundum
Helipterum jessenii
Helipterum pygmaeum
Isoetopsis graminifolia
Minuria cunninghamii
Olearia lepidophylla
Olearia muelleri
Olearia pimeleoides
* *Onopordurn acaulon*
Podolepis capillaris
Senecio cunninghamii
Senecio glossanthus
Senecio lautus
subsp. *dissectifolius*
Senecio runcinifolius
Senecio magnificus
Senecio quadridentatus
* *Sonchus oleraceus*
Vittadinia cuneata
Waitzia acuminata
* *Xanthium spinosum*

BORAGINACEAE
* *Echium plantagineum*
Halgania cyanea

Halgania lavandulacea
* *Heliotropium europaeum*
Omphalolappula concava

BRASSICACEAE
* *Alyssum linifolium*
Arabidella trisecta
* *Brassica tournefortii*
* *Carrichtera annua*
Harmsiodoxa blennodioides
* *Lepidium africanum*
Lepidium leptopetalum
* *Sisymbrium erysimoides*
* *Sisymbrium irio*
* *Sisymbrium orientale*

CAESALPINIACEAE
Cassia eremophila var. *coriacea*
Cassia eremophila var. *eremophila*
Cassia eremophila var. *platypoda*

CAMPANULACEAE
Wahlenbergia communis

CARYOPHYLLACEAE
* *Hernaria hirsuta*
* *Silene apetala*
Spergularia rubra

CASSYTHACEAE
Cassytha melantha
Rhagodia spinescens

CASUARINACEAE
Casuarina cristata subsp. *pauper*

CHENOPODIACEAE
Atriplex holocarpa
Atriplex prostrata
Atriplex spinibractea
Atriplex suberecta
Atriplex vesicaria
* *Chenopodium album*
* *Chenopodium curvispicatum*
Chenopodium desertorum subsp. *pseudomicrophyllum*
* *Chenopodium murale*
Chenopodium pumilio
Dissocarpus paradoxus
Einadia nutans
Enchylaena tomentosa
Eriochiton sclerolaenoides
Maireana pentatropis
Maireana pyramidata
Maireana radiata
Maireana sedifolia
Maireana trichoptera
Maireana triptera
Maireana turbinata
Osteocarpum acroptera
Rhagodia ulicina
Salsola kali
Scleroblitum atriplicinum
Sclerolaena brachyptera
Sclerolaena diacantha
Sclerolaena divaricata
Sclerolaena obliquicuspis
Sclerolaena patenticuspis
Sclerolaena parviflora
Sclerolaena tricuspis
Sclerolaena ventricosa

CONVOLVULACEAE
Convolvulus erubescens

CRASSULACEAE
Crassula colorata

CUCURBITACEAE
* *Citrullus lanatus*
* *Cucumis myriocarpus*
Zehneria micrantha

EUPHORBIACEAE
Beyeria opaca
Chamaesyce drummondii

FABACEAE
Aotus ericoides
Bossiaea walkeri
Eutaxia microphylla var. *microphylla*
* *Medicago laciniata*
* *Medicago minima*
* *Medicago polymorpha*
Templetonia egena
Templetonia sulcata

GERANIACEAE
Erodium cicutarium
Erodium crinitum

GOODENIACEAE
Goodenia pusilliflora
Goodenia sp.
Goodenia varia

GYROSTEMONACEAE
Codonocarpus cotonifolius

HALORAGACEAE
Haloragis odontocarpa

LAMIACEAE
* *Marrubium vulgare*
* *Salvia verbenaca*
Teucrium racemosum

LINACEAE
Linum marginale

LORANTHACEAE
Amyema miquelii
Amyema preissii

MALVACEAE
Lavatera plebeia
* *Malva parviflora*

MIMOSACEAE
Acacia aneura
Acacia brachybotrya
Acacia colletioides
Acacia hakeoides
Acacia ligulata
Acacia microcarpa
Acacia oswaldii
Acacia rigens
Acacia sclerophylla
Acacia wilhelmiana

MYOPORACEAE
Eremophila glabra
Eremophila longifolia
Eremophila maculata
Eremophila oppositifolia
Eremophila sturtii
Myoporum platycarpum

MYRTACEAE
Baeckea crassifolia
Eucalyptus camaldulensis
Eucalyptus dumosa
Eucalyptus gracilis
Eucalyptus incrassata
* *Eucalyptus kruseana*
Eucalyptus largiflorens
Eucalyptus leptophylla
Eucalyptus oleosa
Eucalyptus porosa
Eucalyptus socialis
* *Eucalyptus steedmanii*
Melaleuca lanceolata

OXALIDACEAE
Oxalis corniculata
* *Oxalis pes-caprae*

PAPAVERACEAE
* *Papaver hybridum*

PITTOSPORACEAE
Billardiera versicolor
Pittosporum phillyraeoides

PLANTAGINACEAE
Plantago cunninghamii

POLYGONACEAE
* *Emex australis*
Rumex sp.

PORTULACACEAE
Calandrinia eremaea
Portulaca oleracea

PROTEACEAE
Grevillea huegelii
Hakea leucoptera

RUTACEAE
Geijera parviflora

SANTALACEAE
Exocarpos aphyllus
Exocarpos sparteus
Santalum acuminatum

SAPINDACEAE
Dodonaea viscosa
  subsp. *angustissima*
Alectryon oleifolius
  subsp. *canescens*

SCROPHULARIACEAE
Limosella curdieana
Morgania floribunda
* *Verbascum virgatum*

SOLANACEAE
Lycium australe
* *Lycium ferocissimum*
* *Nicotiana glauca*
Nicotiana goodspeedii
Nicotiana sp.
Solanum esuriale

URTICACEAE
Parietaria debilis

VERBENACEAE
* *Verbena supina*

ZYGOPHYLLACEAE
Nitraria billardieri
Tribulus terrestris
Zygophyllum ammophilum
Zygophyllum apiculatum
Zygophyllum aurantiacum
Zygophyllum billardieri
Zygophyllum crenatum
Zygophyllum iodocarpum
Zygophyllum ovatum

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Floristics and vegetation biomass of a forest catchment, Kioloa, south coastal New South Wales

J. Ash and C. Helman

Abstract

Ash, J. & Helman, C. (The Edith and Joy London Foundation, Australian National University, Kioloa, Australia 2539) 1990. Floristics and vegetation biomass of a forest catchment, Kioloa, south coastal New South Wales. Cunninghamia 2(2): 167–182.* Butlers Creek near Kioloa (35°33′S 150°22′E) is a monitored forest catchment of 33.2 ha, 1 to 2 km inland and at 17 to 172 m altitude on sandstones of the Murramarang Range.

A polythetic agglomerative classification of trees >5 cm diameter at breast height (d.b.h.) at 285 point-centred quarter sites revealed five vegetation types: 1 – notophyll rainforest associated with south-facing gullies typified by abundant *Acmena smithii, Ceratopetalum apetalum* and *Doryphora sassafras;* 2 – notophyll species around gullies with abundant *Cryptocarya microneura, Doryphora sassafras* and *Callicoma serratifolia*; 3 – *Acacia mabelliae* on slopes above the rainforest gullies together with both notophyll and sclerophyll species; 4 – sclerophyll forest on mid-slopes with abundant *Eucalyptus maculata*, merging with; 5 – sclerophyll forest on steep upper slopes with abundant *E. botryoides* on eastern facing slopes and *E. pilularis* on southern slopes. Fires periodically burn the sclerophyll and *Acacia mabelliae* forest but rarely enter the rainforest gullies.

Biomass of trees and shrubs was estimated from regression equations relating $\log_{10}$ d.b.h. with $\log_{10}$ wood volume, $\log_{10}$ bark volume, wood and bark density, the number and average volume of 2 cm diameter branches, and leaf weight on these branches. Separate equations were derived for *Eucalyptus* species and notophyll species, and applied to the measurements of d.b.h. from the point-centred quarter survey. Tree biomass averaged 510 t ha^{-1}, of which 86% was *Eucalyptus*, and comprised 97% of total biomass for the catchment. Root biomass declined from 18% in saplings to 12% in the largest trees, and overall, 14% of biomass was below ground. *Eucalyptus* net wood and bark production in the sclerophyll forest was estimated as 12.8 t $ha^{-1}yr^{-1}$ and 2.9 t $ha^{-1}yr^{-1}$ in the intermediate and notophyll forest, excluding notophyll species. Selective logging of *Eucalyptus* >50 cm d.b.h. removed about 2.4 trees ha^{-1}, about 2.7% of the total tree biomass.

The size threshold for inclusion in surveys is discussed in relation to the floristic analysis, and the floristics and biomass of the catchment are considered in their regional context.

Introduction

Some years after the Australian National University was given the property now known as the Edith and Joy London Foundation, a small forested catchment was set aside for long-term monitoring and experimentation. An initial floristic survey was made in 1980, before the catchment was selectively logged and a second survey was made in 1984 (Helman 1981 1984). A forest biomass survey was made at the time of logging (Ash & Southern 1982). This paper presents background information on the catchment and the results of these surveys. The study area is the catchment of a stream-gauging weir on

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Butlers Creek at Kioloa (35°33′S 150°22′E Figure 1), on the south coast of New South Wales; has an area of 33.2 ha, and extends from the weir at 17 m altitude to 100 to 172 m altitude on the divide of the Murramarang Range. The catchment is shaped like a portion of a basin, the lower half having slopes of 10° to 15° and the upper half 25° to 35°, with 2.6 km of drainage channels converging on the weir.

Geology and soils

The substrate is mostly Permian sandstone of the Shoalhaven group (Pogson 1972), which outcrops as boulders and low cliffs along the steep upper slopes of the catchment, and also as pavements on the lower slopes. The ridge forming the north-eastern divide has a capping of essexite, an instrusive alkaline gabbro, and essexite boulders occur downslope (Figure 1).

The soils vary with the nature and depth of the bedrock. On sandstone the profile typically passes from a dark sandy organic ‘O’ horizon through a grey leached sandy ‘A’ horizon, to a mottled yellow-grey ‘B’ horizon with a high clay content, overlying partially weathered sandstone. Quartz pebbles and sandstone fragments occur throughout the profiles. The depth of the profile varies from 30 cm on steep slopes to more than one metre on the gentler lower slopes. Enclosed depressions on the sandstone pavements have highly organic soils and had a water table at a depth of 30 to 50 cm. On essexite the soil forms a matrix between 10 to 50 cm diameter boulders, and the profile passes from a dark organic layer into brown and grey clays within 20 to 30 cm. Downslope of the essexite, on a sandstone substrate, the soil has intermediate characteristics.

Soil water drainage is impeded by clay and iron-rich layers in the ‘B’ horizon. Three soil water regimes may be identified: sandstone soils on slopes with water available at depth, gullies and depressions in sandstone with a water table near the surface, and the essexite ridge with limited surface water availability.

Climate

Mean daily temperatures range from 9° to 16°C in July and 17° to 23°C in January with extremes of 0° and 40°C. Frosts are infrequent in the near-coastal forests. The mean monthly rainfall is about 100 mm with a uniform distribution through the year, while pan evaporation increases from about 40 mm in July to 120 mm in January. Plant growth is probably limited by low temperatures in winter and by water deficits in most summers. The steep south-facing slopes and gullies in the catchment are more humid throughout the year.

Vegetation

The vegetation comprises both sclerophyll and notophyll-rainforest species and varies in response to substrate, topography, aspect and human interference. Except for tracks, the catchment is forested and has a canopy height of up to 40 m. Sclerophyll species (mostly *Eucalyptus* spp.) occur throughout the catchment but are less abundant in the south-facing gullies. Notophyll trees and shrubs are associated with gullies and adjacent slopes (Figure 1). Large notophyll trees are restricted to the gullies but smaller individuals occur on the slopes. The understorey varies with site conditions. *Gahnia sieberana* is abundant in wetter areas, ferns (e.g. *Culcita dubia* and *Histiopteris incisa*) are abundant in shady conditions and *Pteridium esculentum* and grasses are abundant in

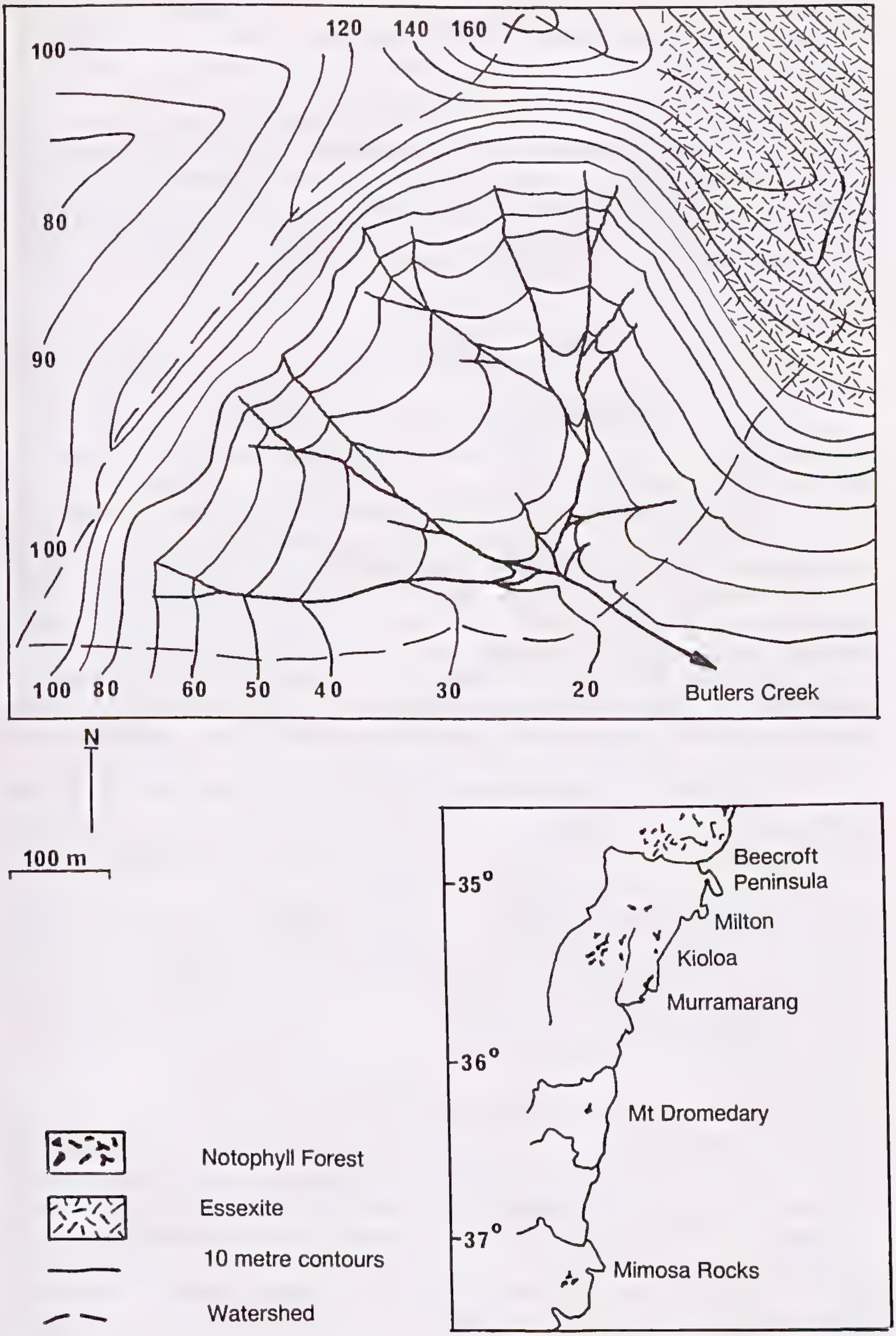

Figure 1. Maps showing the location of Kioloa and other major notophyll forest patches in southern New South Wales (Inset), and the geology and topography of the Butlers Creek catchment.

clearings and open eucalypt forest. *Macrozamia communis* is restricted to sandstone outcrops near the rim of the catchment.

Site history

Timber has been taken from the catchment since the 1880s, most intensively in the period 1910–1926 (pers. comm. J. London). The lower slopes have been most frequently logged. Old tree stumps indicate that the forest used to contain many large trees, of which there are now few living examples. The logging history and regeneration are typical of adjacent forests.

Methods

Floristic classification of woody dicotyledons

The point-centred quarter survey method was used (Curtis 1959, Mueller-Dombois and Ellenberg 1974) with a minimum size of 5 cm diameter at breast height (d.b.h.). At each point, quadrants were defined by the four cardinal points of a magnetic compass. In each quadrant the nearest living tree, and any nearer stumps of felled trees were recorded by their species, and distance from the centre point. Points were chosen at predetermined regular intervals along the catchment contours. In 1981, 132 points were located at 40 m intervals along each 10 m contour between 20 m and 60 m altitudes and at 120 m intervals along each 10 m contour between 70 m and 140 m altitude. Selective logging interfered with sampling the upper part of the catchment in 1981, and a second survey of 153 points was conducted in 1984, at intermediate locations on the contours, extending up to 170 m altitude. Despite logging during 1981–82 only 0.5% of the trees selected during the 1984 survey were felled, so major changes in the forest composition between the surveys were not expected. Tree ferns, *Macrozamia communis* and *Livistona australis* were minor components of the woody vegetation, and were excluded from the survey.

The species abundance at each point was used to classify the vegetation using an agglomerative polythetic algorithm (CLUSTAN) with a Bray-Curtis distance measure (Bray and Curtis 1957) and a space-conserving sorting stratey using group averages (Wishart 1978). The resulting vegetation types were mapped to facilitate interpretation. The results of the two surveys were very similar and they were combined for presentation here.

Estimation of biomass

Various components of the biomass in the catchment were estimated, using several procedures. Total tree biomass (>5 cm d.b.h.) was estimated from the abundance of trees as determined by the floristic survey, their d.b.h. and regression equations linking d.b.h. with biomass. A similar procedure was used for shrubs and saplings (0–5 cm d.b.h.), for which a point-centred quarter survey of 190 points was undertaken at 10 m intervals along the 35 m and 100 m contours.

Tree biomass was estimated in several components: wood and bark volume above and below ground, wood density in relation to d.b.h., bark density, the number of branches of 2 cm wood diameter, their volume, and the number, dry-weight and area of leaves on branches of 2 cm wood diameter. The relationships between these components and non-destructive measurements (d.b.h.) were determined from uprooted, fallen and felled trees in and around the catchment. In many cases one or more biomass components could not be estimated from a tree. Because of its importance for biomass estimation, particular attention was given to measurements of d.b.h. and possible errors in the survey d.b.h. measurements.

Trunk d.b.h. calculated from a circumference tape overestimates the mean diameter if the trunk is not circular. An examination of 50 *Eucalyptus maculata* stumps showed that the ratio of the longest to the shortest diameter ranged from 1.0 to 1.35 with a mean of about 1.15. In small trees the sections are usually elliptical, but as buttresses develop the shape is convoluted and the circumference tape passes across the buttresses, enclosing spaces. Relative to a circular trunk of the same cross-sectional area, the tape measurement increases from 1.0 to about 1.5 for highly buttressed trees. Buttressing becomes significant on eucalypts larger than about 120 cm d.b.h. Survey d.b.h. values (D) were, therefore, adjusted (d) by the formula:

$$d = D - 0.00053D^2$$

Wood volumes were estimated from measurements of corrected (circular) trunk, root and branch diameters at intervals of 2 to 5 m along every stem and branch down to 2 cm diameter and for roots down to 0.5 cm diameter. Branches of 2 cm wood diameter were removed from the upper and lower parts of tree canopies of six species, and the volume of the branches, leaf dry weight and leaf areas were measured. Root volumes were estimated from the proportion of the circumference which was exposed on uprooted trees. Bark volumes were estimated from bark thickness, and correction coefficients were determined for species with fissured bark by estimating the volume of bark in relation to the volume if the tree had a smooth bark.

Wood density generally increased from the sapwood to the heartwood, and a linear increase in density with trunk diameter was assumed, reaching heartwood density at the maximum observed diameter. Both sapwood and heartwood densities were estimated for several common species and supplemented by published densities corrected from 12% to 0% moisture content (Cause et al. 1974). Bark density did not show obvious variation with tree size so a single value was used for each species.

Total volume of the floristic survey trees was calculated from corrected trunk diameter (d) by substitution into the regression equations for each component of wood and bark volume and then converted to biomass by multiplication by the appropriate wood density and the bark density. Regression equations were also derived to determine tree biomass directly from corrected trunk diameter.

In addition to direct measurements of root volume on uprooted trees, an independent estimate of root biomass was made by excavating tree roots of less than 5 cm diameter from thirty 0.1 m^2 pits dug to a depth of 15 cm below the lowest recorded roots, typically 40 to 90 cm below the surface, at the base of the B horizon. Some roots penetrating fissures in the sandstone were probably overlooked by this procedure. Fifteen pits were equally spaced along each of the 30 m and 100 m contours.

Fallen logs (>5 cm diameter) were sampled by recording the cross-sectional area of logs along the 25 m, 50 m and 100 m contours; a total distance of 2.25

km. Logged trees were recorded in the 1984 survey, the next nearest tree being used in the floristic analysis. A second estimate of logged trees was made by

Table 1. Percentage frequency of species in forest types (1 to 5) and percentage of total tree biomass. + = present

Species	Sclerophyll (1)	Sclerophyll (2)	Interm (3)	Notophyll (4)	Notophyll (5)	Biomass %
Acacia implexa	0.2	0.8				0.11
Acacia maidenii						0.03
Acacia mabelliae	0.4	3.2	19.0	+	4.3	6.59
Acmena smithii	0.5	0.8	0.4	0.8	9.4	2.67
Acronychia oblongifolia			0.6	0.2	0.2	0.02
Alectryon subcinereus				+	+	+
Astrotricha latifolia				+	+	+
Backhousia myrtifolia				0.4	0.4	0.63
Baloghia lucida				+	+	+
Callicoma serratifolia		0.4	0.6	1.2	0.6	0.25
Ceratopetalum apetalum		0.2	+	+	1.6	0.66
Claoxylon australe				+	0.2	0.01
Clerodendron tomentosum				+	0.2	0.01
Commersonia fraseri			1.9	0.2	0.2	0.10
Cryptocarya glaucescens				0.4	+	0.05
Cryptocarya microneura	0.4	0.2	2.0	2.3	1.3	1.59
Diospyros australis				+	+	0.02
Doryphora sassafras			0.2	3.0	0.9	0.49
Elaeocarpus reticulatus			0.2	0.2	+	0.04
Endiandra sieberi				+	0.2	0.01
Eucalyptus agglomerata	+					+
Eucalyptus botryoides	4.3	0.9	1.7	0.6	0.2	13.64
Eucalyptus globoidea	+		0.2			0.41
Eucalyptus gummifera	+					0.69
Eucalyptus maculata	0.2	13.5	2.8	+	0.6	59.46
Eucalyptus pilularis	2.3	3.9	3.0			11.55
Eucalyptus tereticornis		0.2	0.2			0.76
Eupomatia laurina			0.2			0.01
Exocarpus cupressiformis						0.01
Ficus coronata		0.2	0.2	1.1	0.6	0.13
Glochidion ferdinandi				+	0.2	0.14
Guioa semiglauca				+	+	+
Hedycarya angustifolia			0.2	0.2		0.01
Notolaea longifolia				+	+	+
Palmeria scandens				+	+	+
Pittosporum revolutum				+	+	0.02
Pittosporum undulatum				+	+	0.01
Pomaderris aspera				+	+	+
Prostanthera lasianthos				+	+	0.02
Psychotria loniceroides				+	+	+
Rapanea howittiana				0.2	+	0.01
Rhodamnia rubescens			0.2	+	0.4	0.08
Synoum glandulosum			1.1	0.6	0.2	0.03
Trema aspera				+	0.2	0.01
Tristianiopsis collina				0.2	+	0.02
Total	8.3	24.1	34.6	21.8	1.3	100

recording stumps in a 10 m wide transect along contours at 10 m altitude intervals.

Distinct regular growth rings were apparent in logged *Eucalyptus* and were interpreted as annual growth increments. Observations on 67 trees were used to derive a relationship between trunk diameter and annual increment from which annual production could be estimated.

Herbaceous vegetation (stems <1.3 m high) and litter (<5 cm diameter) were removed, dried and weighed from 33 quadrats each $1 m^2$ equally spaced on the 25 m, 50 m and 100 m contours.

Results

Floristic classification of woody dicotyledons

The distribution of selected abundant species at the sampling points is shown in Figure 2. Species such as *Acacia mabelliae* are widespread, while *Acmena smithii, Cryptocarya microneura* and *Doryphora sassafras* occur in gullies and at lower altitudes, with *Eucalyptus* spp. extending onto the upper slopes.

The classification procedure defined seven classes at the 0.75 dissimilarity level which may be combined as five major vegetation types, two of which are sclerophyll dominated, two are notophyll dominated and one is intermediate. The composition of these types is shown in Table 1 and their distribution is shown in Figure 3. The characteristics of these types are as follows

1. *Eucalyptus botryoides* (52% of trunks) and *E. pilularis* (27%) characterise two classes which form a sclerophyll vegetation type that occurs on the higher and steeper slopes in the catchment. *E. botryoides* dominated communities occurred more commonly on the east-facing slopes in the southwest corner of the catchment, while *E. pilularis* dominated the southwest-facing communities of the eastern section.

2. A more abundant sclerophyll type is characterised by *E. maculata* (56% of trunks), often forming a single-dominant community on the lower, gentle ridges in the centre and southeast of the catchment, but also occuring with *E. botryoides* (5%) or *E. pilularis* (9%) on higher and steeper slopes.

3. An intermediate vegetation type is characterised by *Acacia mabelliae* (55% of trunks), forming a low-canopied community (5 to 15 m high) between large, widely-spaced eucalypts, but the outliers of this group include notophyll species e.g. *Cryptocarya microneura* (6%), *Commersonia fraseri* (5%), *Callicoma serratifolia* (2%) and *Synoum glandulosum* (3%), linking it floristically with rainforest. This intermediate type occurs in various locations including above rainforest gully edges, in gaps in the rainforest, and above rainforest on steep fire-protected east- and south-facing small ridges.

4. A notophyll rainforest type on well drained sites, dominated by *Cryptocarya microneura* (20% of trunks), *Doryphora sassafras* (27%), or *Callicoma serratifolia* (10%) with variable combinations of subordinate notophyll species, including *Ficus coronata* (10%), *Backhousia myrtifolia* (3%) and *Acmena smithii* (7%). This rainforest type occurs around the edge of the main rainforest, higher in gullies, and in places where it is more vulnerable to desiccation from hot winds and to disturbance from fire, logging and windthrow. This group corresponds to disturbed and successional forest of types described as the

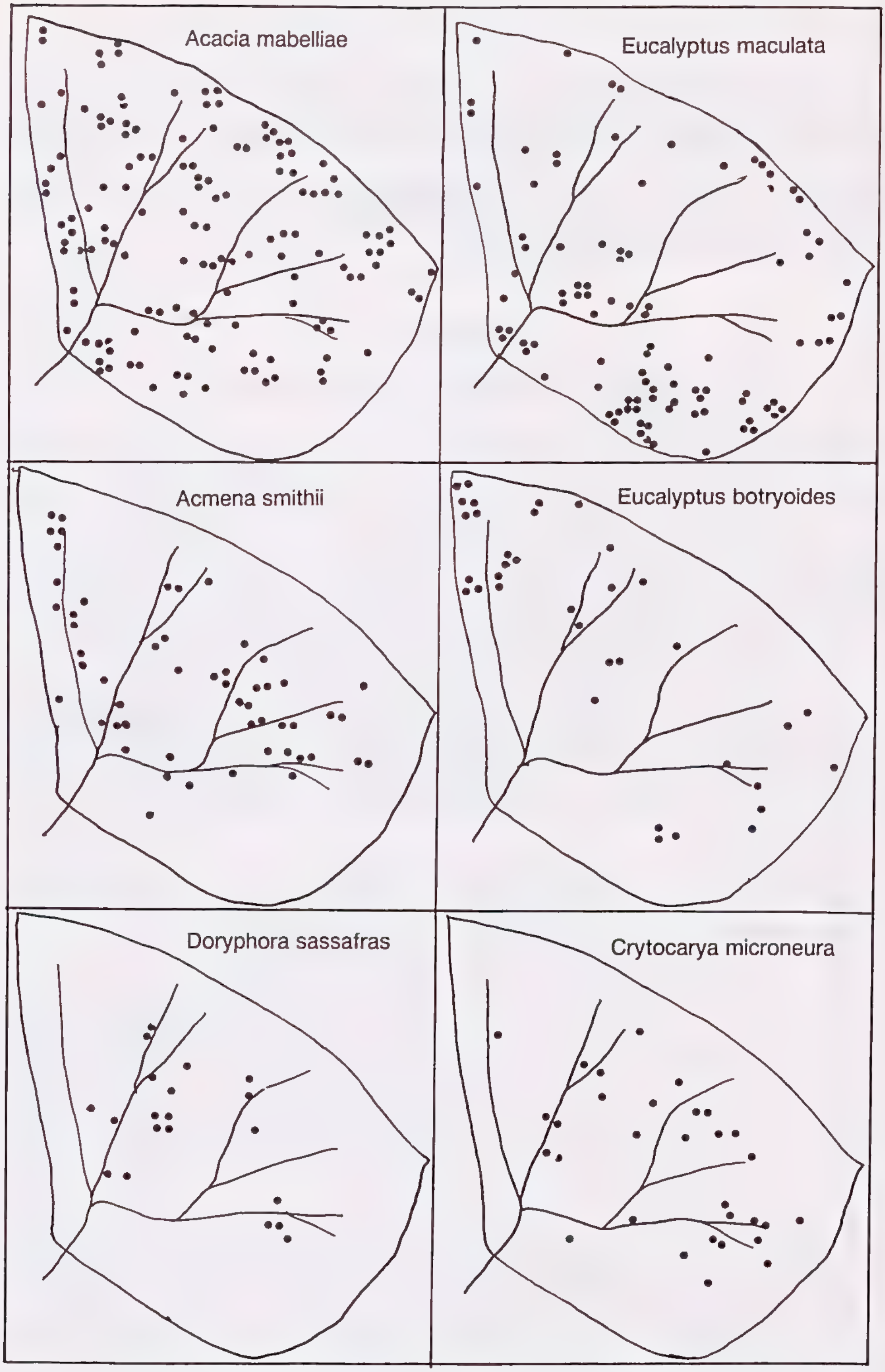

Figure 2. Maps showing trees of selected species at sampling points in the Butlers Creek catchment.

Ceratopetalum/Doryphora association (Baur 1957), notophyll vine forest (Webb 1959), and the warm temperature community (type 8) of Helman (1983).

5. Notophyll rainforest characterised by *Acmena smithii* (43% of trunks) which is abundant on wetter sites and the fire-protected south- and southeast-facing gullies. In the most protected places other species include *Doryphora sassafrass* (4%) and *Ceratopetalum apetalum* (7%). More commonly, away from the gully centres, a variety of other species occur including *Cryptocarya microneura* (6%), *Ficus coronata* (3%), *Backhousia myrtifolia* (2%) and *Acacia mabelliae* (20%). The latter vegetation type merges with the type 4 vegetation.

Tree biomass

Observations were made on the dimensions of 85 *Eucalyptus*, 16 *Acacia mabelliae* and 52 notophyll rainforest trees. It was found that d.b.h. and tree volume regressions were similar in all species (Table 2) but that wood densities varied significantly (Table 3) and for calculating tree biomass the following equations were used to relate density (g) to d.b.h. (d):

in *Eucalyptus*, $g = 0.5 + 0.005\ d$,

in *Commersonia* and *Trema*, $g = 0.25 + 0.0015\ d$,

in other notophyll species, $g = 0.5 + 0.003\ d$.

The resulting equations for predicting biomass from d.b.h. are given in Table 2. It was apparent that the percentage of tree volume below ground declined from about 18% at 1 cm d.b.h. to 12% at 150 cm d.b.h. Leaf or phyllode weight on 2

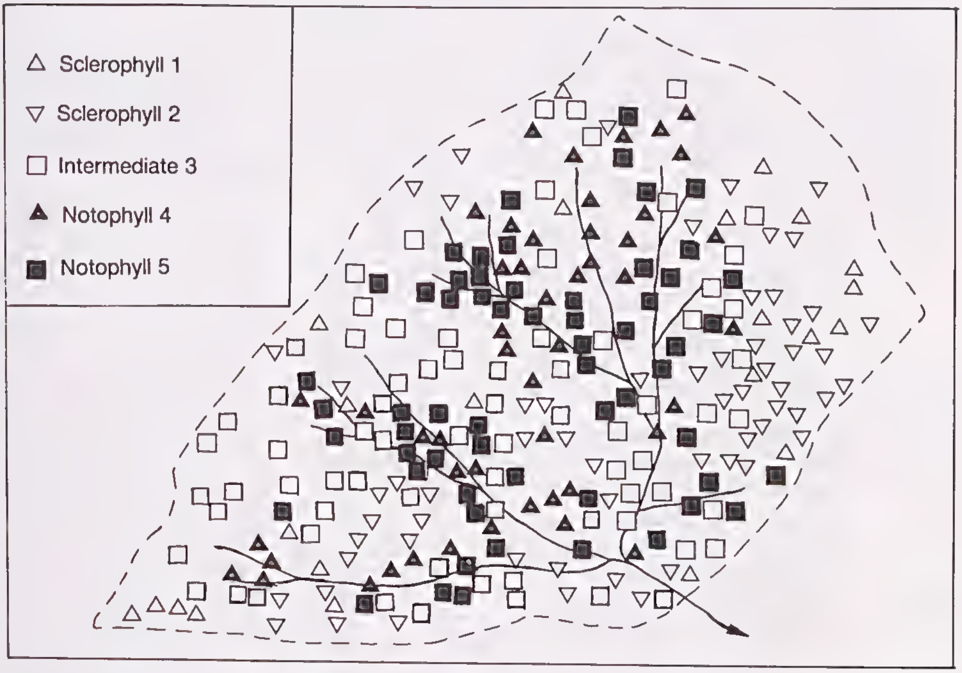

Figure 3. Map showing the distribution of the five vegetation types at sampling points in Butlers Creek catchment.

cm diameter branches varied considerably between species but total areas were similar (Table 4).

Forest biomass

From the survey of trunk diameter it was estimated that individual tree biomass ranged up to 80,000 kg, though the mean was only 898 kg (±111 s.e., n = 1140). This highly skewed distribution was approximated by a Weibull distribution (Candy 1983) in which the expected value (y, kg) was set equal to the mean biomass and the tail was set such that, as observed, seven trees should exceed 15,000 kg, i.e.

$$y = 305.4\ G\ (1 + 1/0.417)$$

The sampling distribution of the mean of this highly skewed distribution was examined by simulating the survey 100 times, picking 1140 trees at random each time, which yielded normally distributed estimates of the mean (Kolmogorov-Smirnov test, $p = 0.98$) with a standard error of ±89 kg, slightly smaller than the observed standard error (±111 kg). It was also determined by simulation that surveys of 500 trees would have yielded a normally distributed mean but this property would be lost with samples of only 100 trees. These results indicate that despite the highly skewed distribution of tree biomass, the calculated mean biomass is a reliable measure for determining forest biomass.

Table 2. Relationships of $\log^{10}$ tree components (y, number or kg or 0.001 m^3) with $\log_{10}$ trunk diameter (d, cm):
$\log_{10}y = a + b \log_{10}d$ where, n = number of observations, r = Pearson correlation, a = intercept, b = slope, and s.e. = standard error. Above ground components (A.G.) are indicated. 2 cm diameter branch wood volume was estimated as 0.0011 m^3. Biomass and biomass increment were derived from the other equations, density and growth ring width. Underground bark and 2 cm branch bark biomass were estimated as 10% of the wood biomass. The biomass of *Commersonia* and *Trema* is about half that estimated for other notophyll species because of their low wood density. The equations are based on measurements of: *Eucalyptus maculata* (30), *E. pilularis* (47), *E. botryoides* (8), *Acacia mabelliae* (16), *Commersonia fraseri* (12), *Acmena smithii* (26), *Backhousia myrtifolia* (11), *Cryptocarya microneura* (2), *Doryphora sassafras* (1).

Species	Component	n	r	a	b	s.e.
All	Wood Volume (A.G.)	133	.994	−0.69	2.41	.106
"	Number 2 cm branches	78	.951	−0.15	1.29	.151
"	Bark Volume (A.G.)	17	.988	−1.01	2.12	.151
"	Root crown wood Volume	53	.989	−2.42	2.56	.161
"	Root wood Volume	54	.972	−0.96	2.03	.217
Eucalyptus	Wood Volume (A.G.)	66	.996	−0.72	2.43	.109
"	Number 2 cm branches	31	.961	−0.51	1.51	.158
"	Bark Volume (A.G.)	13	.987	−0.83	2.02	.127
"	Root crown wood Volume	40	.991	−2.46	2.59	.165
"	Root wood Volume	41	.977	−0.91	2.01	.206
"	Biomass, kg	–	–	−0.92	2.56	–
"	Biomass increment, kg yr^{-1}	–	–	−0.35	1.37	–
Notophyll	Wood Volume (A.G.)	67	.989	−0.63	2.34	.101
"	Number 2 cm branches	47	.956	−0.03	1.22	.120
"	Bark Volume (A.G.)	4	.992	−1.19	2.21	.085
"	Root crown wood Volume	13	.978	−2.19	2.38	.148
"	Root wood Volume	13	.921	−0.76	1.75	.216
"	Biomass, kg	–	–	−0.72	2.39	–

The mean point to tree distances (4.20 m ±0.12 s.e., n = 285) and point to shrub distances (2.62 ±0.16 s.e., n = 190) provided estimates of abundance per hectare. There was marked variation between the sclerophyll dominated (78% *Eucalyptus*) upper slopes, with 425 trees ha^{-1} and 1047 shrubs ha^{-1}, and the notophyll dominated (13% *Eucalyptus*) lower slopes with 775 trees ha^{-1} and 3300 shrubs ha^{-1}. The *Eucalyptus* are, however, generally larger trees that the notophyll species and total tree biomass was estimated as 588 t ha^{-1} (± 104 s.e.) on the upper slopes and 347 t ha^{-1} (±62 s.e.) on the lower slopes, with an average of 510 t ha^{-1} for the whole catchment. Tree foliage averaged 6.31 kg (±0.25 s.e.) or 3.58 t ha^{-1} (±0.24 s.e.). Tree roots of less than 5 cm diameter were estimated at 11.6 t ha^{-1} (95% range 9.2 to 18.2 t ha^{-1}). The percentage of biomass contributed by each species is shown in Table 1, from which it is apparent that the *Eucalyptus* species account for 86% of tree biomass, though they only account for 38% of tree trunks.

Mean shrub biomass was similar throughout the catchment (1.58 kg ±0.07 s.e., n = 760 for volume) yielding 1.74 t ha^{-1} (±0.11 s.e.) in the upper catchment and 4.73 t ha^{-1} (±0.40 s.e.) in the lower catchment with an average of 2.31 t ha^{-1} (±0.20 s.e.).

Herbs were estimated to comprise 0.61 t ha^{-1} (95% range 0.57 to 0.75 t ha^{-1}), litter comprised 4.9 t ha^{-1} (95% range 4.3 to 5.6 t ha^{-1}), and fallen logs 8.4 t ha^{-1}. Of the total biomass (530 t ha^{-1} ±73 s.e.) 97% was contained in the trees

Table 3. Wood and bark density (g cm^{-3}) of selected species. Values determined from this study are given with standard deviations (n = 3); other values are from Cause et al. (1974) adjusted to zero moisture content.

Species	Heartwood	Sapwood	Bark
Acacia mabelliae	.55	.35±.09	
Acmena smithii	.81	.65±.08	.44±.01
Acronychia oblongifolia	.81	.56	
Backhousia myrtifolia	.93, .8±.04	.65	.41±.20
Callicoma serratifolia	.51		
Ceratopetalum apetalum	.82	.51	
Commersonia fraseri	.35, .28±.04	.26	.32±.04
Cryptocarya glaucescens	.56		
Cryptocarya microneura	.70		
Diospyros australis	.65 – 1.1		
Doryphora sassafras	.52 – .6		
Elaeocarpus reticulatus	.4 – .65		
Eucalyptus botryoides	1.1		
Eucalyptus globoidea	.85 – 1.12		
Eucalyptus gummifera	.89		
Eucalyptus maculata	.89	.53±.05	.33±.03
Eucalyptus pilularis	.82 – 1.25	.49±.03	.24±.03
Eucalyptus tereticornis	.89		
Exocarpus cupressiformis	.74		
Ficus coronata	.41		
Glochidion ferdinandi	.62 – .75		
Pittosporum undulatum	.76		
Rapanea howittiana	.81		
Rhodamnia rubescens	.68		
Synoum glandulosum	.59		
Trema aspera	.35		
Tristianiopsis collina	.89		

and a further 1.6% was in fallen logs. The very small contribution by herbs (0.1%) and litter (0.9%) partly reflect the burning of the catchment in the previous year. Partly for this reason, 54% of herb biomass was below ground, contrasting with 17% of shrubs, 13% of trees and 14% of total biomass. The number of trees felled in logging operations was estimated as 2.8 ha^{-1} (±1.7 s.e.) from point-centred quarter records of stumps and as 2.4 ha^{-1} (±0.2 s.e.) from transects. Stump diameters averaged 66.5 cm d.b.h. (±1.5 s.e., n = 30), corresponding to a tree biomass of 12.5 t ha^{-1}, or about 2.5% of total tree biomass, of which about 60% was removed from the catchment.

Annual net production of *Eucalyptus* was estimated from the growth ring increments shown in Figure 4. *Eucalyptus* production was estimated as 12.8t ha^{-1} yr^{-1} in the upper catchment and 2.9 t ha^{-1} yr^{-1} in the lower catchment.

Table 4. Total oven-dry leaf or phyllode weight, and total leaf area on 2 cm diameter branches from upper and lower parts of the canopy.

Species	Total leaf weight, g mean±s.d.	n	Total leaf area, m^2 mean
Eucalyptus maculata	125±47	(12)	1.25
Eucalyptus pilularis	198±110	(6)	1.91
Acmena smithii	144±56	(9)	1.75
Backhousia myrtifolia	61± 30	(15)	1.12
Acacia mabelliae	203±60	(9)	2.03
Commersonia fraseri	83±25	(7)	1.58

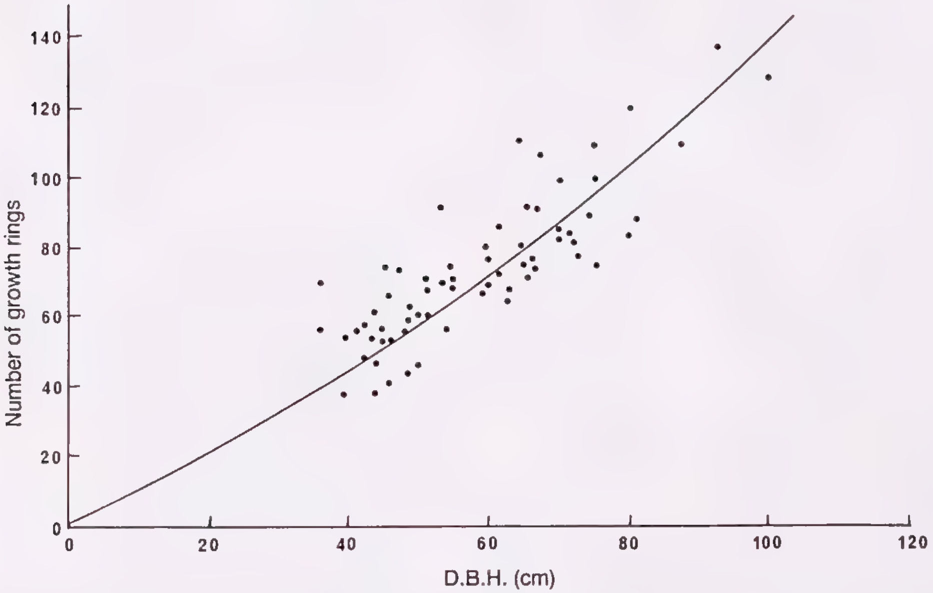

Figure 4. Scatter diagram showing the number of growth rings and trunk wood diameter of *Eucalyptus* spp. at Butlers Creek. The relationship is summarised by a hand-drawn curve passing through the origin.

Assuming similar ratios of production to biomass in the other tree species the net production in the whole catchment would be about 10.3 t ha^{-1} yr^{-1}.

Discussion

The point-centred quarter survey method proved to be suitable both for recording quantitative floristic information on woody species and for recording information suitable for estimating forest biomass. Since then Diggle (1983) has suggested that the 'T-square' sampling procedure yields superior spatial statistics though it only records two trees at each locality. Whichever procedure is used, however, a critical parameter which may not receive sufficient attention is the minimum trunk diameter for inclusion in a survey. Because there is typically an inverse relationship between the tree size and frequency, a survey samples most information about trees slightly larger than the minimum size. This has several implications, firstly, since some species reach larger sizes than others their relative abundance will depend on the size limit. In the present survey *Acacia mabelliae*, exceeding 5 cm d.b.h., were recorded at 47% of the survey points but if a 25 cm d.b.h. limit had been selected instead then they might only have been recorded at 28% of the survey points, the latter mostly restricted to the lower slopes. Evidently changing the d.b.h. threshold could change the definition of vegetation types and would have significantly changed the abundance and boundaries of these types. These thresholds may be of particular signficance in fire-prone vegetation where small trees may be killed by fire.

The vegetation types defined by the cluster analysis had a high spatial contiguity when mapped (Figure 3) and can be interpreted as a catena from ridges to gullies modified by aspect. In part this interpretation reflects soil moisture availability and humidity but it is also a consequence of associated differences in vegetation flammability, resulting from the interaction between the microclimate and vegetation type. A fire in September 1980 burned virtually all the sclerophyll forest, much of the intermediate forest but only the margins of the notophyll forest, leaving the deeper gullies unburned. The vegetation in the middle parts of the catena is evidently relatively variable, being colonised by *Acacia mabelliae* and notophyll species after fires but saplings of these species are likely to die in subsequent fires. In the absence of fires for many years it is possible that notophyll forest could extend upslope.

The notophyll rainforest in the catchment is typical of many other small patches in the region and is close to the southern limit of about eleven species (*Callicoma serratifolia, Ceratopetalum apetalum, Clerodendrum tomentosum, Cryptocarya microneura, Diospyros australis, Endiandra sieberi, Glochidion ferdinandii, Guioa semiglauca, Rhodamnia rubescens*, and *Palmeria scandens).* The catchment is close to the southern limit of the massive sandstones of the Sydney basin, which may limit the southerly range of some species while other species may be associated with the monzonite and essexite outcrops at Milton, Kioloa and Mt Dromedary (Pogson 1972). It is not clear whether the general southerly decline in numbers of rainforest species represents a stable pattern in equilibrium with the climate, a continuing post-glacial range extension to the south, or even an extinction of southern populations. Evidently several of the rainforest species which are close to their southern limits are reasonably abundant and grow successfully in the catchment, suggesting that the species are not at their climatic limits.

The sclerophyll component of the vegetation is more widespread along the southern coast of New South Wales and these species dominate most of the surrounding forest areas. The balance between *Eucalyptus* and notophyll rainforest species appears to be controlled by fire and is likely to be a consequence of human activity in addition to substrate and climatic factors.

The procedures for estimating forest biomass used in this study follow the usual practice of defining a relationship between an index of tree size, e.g. d.b.h., and tree volume, which is then converted to biomass by measuring wood and bark density (e.g. Whittaker and Woodwell 1968, Westman and Rogers 1980, Feller 1980). This study differs in several aspects, firstly, the entire tree volume was measured down to 2 cm diameter 'standard' branches in contrast to the usual practice of measuring the trunk and a few large representative branches. Secondly, wood density values were adjusted for tree size rather than given as a constant for each species. Thirdly, a broad range of tree sizes were selected to establish reliable slopes for regression equations, and a large number of trees were measured to give confidence to the results. Fourthly, in contrast to most studies, the forest biomass was not measured or calculated for a small plot of trees but for a whole catchment on the basis of an unbiased sample of more than 1100 trees. The biomass estimates can therefore give some measure of the probable variation in forest biomass: a 95% range of 384 to 676 t ha^{-1}. In reality trees are not drawn at random from the forest population but form floristically distinct communities, and the 95% range of tree biomass is likely to be between 220 t ha^{-1} in the notophyll dominated types to 800 t ha^{-1} in the *Eucalyptus* dominated types. This range of values spans virtually all biomass estimates made for humid temperate *Eucalyptus* dominated forests (Ashton 1976, Westman and Rogers 1977, Attiwill 1979, Harrington 1979, Hingston, Turton and Dimmock 1979, Steward, Finn and Aeberli 1979, Feller 1980, Bradstock 1981, Hingston, Dimmock and Turton 1981, Rogers and Westman 1981, Grove and Malajczuk 1985). Local site and floristic variation, in addition to fire and logging history, may partly explain why these published estimates are so variable. The estimate of leaf biomass (3.6 t ha^{-1}) also falls within the same broad range of published values (2.6 to 8.9 t ha^{-1}) for these forests. The percentage of *Eucalyptus* biomass below ground level was estimated as 13% in this study, about 10% in *E. obliqua* and *E. regnans* (Feller 1980) but about 40% in *E. signata* (Westman and Rogers 1971). These results may be compared with other forests (Cannell 1982), from which it is apparent that underground tree biomass (U, %) varies with total tree biomass (B, t ha^{-1}) as

$$U = 47 - 11.9 \log_{10} B, \pm 0.25U \text{ s.e.}$$

giving expected values of about 15% for the forest in this study and those examined by Feller (1980) and 21% for the forest studied by Westman and Rogers (1977). The value for this study is close to that which would be expected.

The estimate of *Eucalyptus* net production in the sclerophyll forest, 12.8 t ha^{-1} yr^{-1}, falls within the range of 4 to 16 t ha^{-1} yr^{-1} estimated in other *Eucalyptus* forests (Attiwill 1979, Hingston et al. 1979, Feller 1980, Bradstock 1981, Hingston et al. 1981, Rogers and Westman 1981, Grove and Malajczuk 1985) but significantly below values for *E. regnans* (> 29 t ha^{-1} yr^{-1}) and *E. sieberi* (> 32 t ha^{-1} yr^{-1}) determined by Ashton (1976).

Neither leaf nor fine root production were included in this study and by comparison with other forests, leaf production of about 2.6 t ha^{-1} yr^{-1} might be expected (Attiwill 1979, Rogers and Westman 1981, Grove and Malajczuk

1985) and fine root production might be of a similar magnitude (Fabiao, Persson and Steen 1985).

It was evident that the *Eucalyptus* reached a much larger size than the notophyll rainforest species, often occurring as emergents above the intermediate and marginal notophyll forest types, and *Eucalyptus* comprised the bulk of the forest biomass. The abundance of notophyll species on the lower slopes was, however, much greater, with a more continuous leaf canopy, and production may be similar. There is a lack of comparative information on the biomass and production of these southern rainforests.

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Index to vegetation maps and related surveys of New South Wales and the Australian Capital Territory (1945–1986)

J. Thomas and H.H. Dlugaj

Abstract

Thomas,[1] *J. & H. H. Dlugaj*[2] *(National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1990. Index to vegetation maps and related surveys of New South Wales and the Australian Capital Territory (1945–1986). Cunninghamia 2(2): 183–196.* An index to vegetation maps of New South Wales is outlined on four separate base maps. Related surveys and their maps are included where vegetation can be keyed to the map. The maps are described briefly in the list of references, indicating the botanical subdivisions of New South Wales to which they refer.

Introduction

Vegetation maps provide an inventory of plant communities and habitats. Changes in vegetation can be followed over periods of time from early explorers' notes to the present. Current vegetation maps are a basic tool for research workers and organisations involved in land-use management. A particular demand for vegetation maps is for environmental impact studies. For these, base-line vegetation data are vital for assessments of impact where various developments are proposed and for revegetation after environmental disturbance.

Until recently, there has been no overall review of vegetation mapping within New South Wales. In 1969 the National Herbarium of New South Wales began mapping in the North West and Central Coast of New South Wales. The long term aim is to prepare maps showing the distribution of vegetation communities throughout the state.

Other institutions have also embarked on state-wide surveys. The Soil Conservation Service of New South Wales is producing a series of district technical manuals encompassing vegetation, soils, geology and land use maps with notes, and a series of land systems maps at a scale of 1:250 000.

Previous vegetation map indexes for New South Wales are listed in Table 1. The most comprehensive of these is a Natural Vegetation map of Australia (Carnahan 1976). Carhahan's index was used as a basis for this index.

Table 1. Map indexes compiled previously

a Carnahan, J.A. (1976). Natural vegetation. In *Atlas of Australian Resources.* Second series. Dept. of National Resources, Canberra.
An index to vegetation maps and related surveys appears on the back of this coloured vegetation map (1:6 000 000). Some of the maps listed here for

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[1] Current address: National Parks & Wildlife Service, Bathurst, Australia 2795.

[2] Current address: 32 Charles Street, Cairns, Australia 4870.

N.S.W. have been omitted in this index because of the general unavailability of unpublished maps.
See also No. 10 in references.

b Department of National Development (1961). *Index to Australian resources maps of 1940–1959.* Canberra, Australia.
Vegetation maps and species distribution maps published between 1940–1959. Soils, landforms, climate, forestry etc. maps are also listed.

c Department of National Development (1966). *Index to Australian resources maps supplement for 1960–1964.* Canberra, Australia.
As above in (b). Also lists Forestry Commission forest type series maps published pre-1960. No supplements after 1964.

d Department of National Development and Energy, Division of National Mapping (NATMAP) (1971-). *Thematic Mapping Bulletin.*
An annual publication listing all known thematic maps produced by government departments in the preceding year. Available from Bureau of Mineral Resources. (P.O. Box 378, Canberra City, A.C.T. 2601).

e Hayden, E.J. (1971). *Natural vegetation of New South Wales.* Unpublished M.Sc. Australian National University, Canberra.
A compilation from previously published and unpublished vegetation maps. Reference maps with notes on the reliability of each are listed.

Types of maps included in this index

This index provides information on the availability of vegetation maps for particular areas of New South Wales. Other maps, such as Land Systems, Soils and Land Use maps frequently include vegetation data in their legends or accompanying texts. The close correlations between vegetation and both soils and land systems make these maps useful in areas lacking vegetation maps and hence some have been included. Generally, broad guidelines similar to those in the Thematic Mapping Bulletin (Division of National Mapping, Canberra) have been adopted:

* The map is primarily concerned with vegetation or useful information about vegetation can be extracted from it.
* The map covers part or all of New South Wales and the Australian Capital Territory. (A.C.T. lands occur within the South Coast and Southern Tablelands botanical subdivisions of N.S.W.).
* The map scale is generally between 1:2 000 and 1:10 000 000.
* The map size is at least B5 (176mm x 250mm).
* Some base map detail is shown.
* The map is generally available to the public.

Floristic lists sometimes include sketch maps of vegetation. These maps are often used in the compilation of larger maps but because the papers are primarily species lists they have not been included here. Pickard (1972), Bryant and Benson (1981) and Keith (1988) have prepared a bibliography of recent floristic lists. Maps in theses and environmental impact statements have not been included because these are either generally unavailable or are mostly based on pre-existing vegetation maps.

The map index (Figures 1–5) and reference list (Table 3)

The map reference list (Table 3) gives a brief description of each map stating type, scale and number of map units. Contents of any accompanying text are indicated. Reliability, and completeness vary considerable from map to map but no attempt has been made to show reliability of vegetation information.

Map coverage has been indicated on the map index of four base maps by noting the number of each map from the map index on the 1:100 000 map grid for New South Wales (Figure 1). The four base maps are for north-western (Figure 2), north-eastern (Figure 3), south-western (Figure 4) and south-eastern (Figure 5) New South Wales. A number in a grid cell indicates either whole or partial coverage of that cell.

The tables and map references

Table 2 summarises the maps relevant to each of the botanical subdivisions of the state as recognised by the National Herbarium of New South Wales (Jacobs and Pickard 1981). The references in Tables 1 & 3 are arranged alphabetically by authors and chronologically within authors. Entry into the bibliography can be done either by looking at the figures for any map available for an area or by botanical subdivisions.

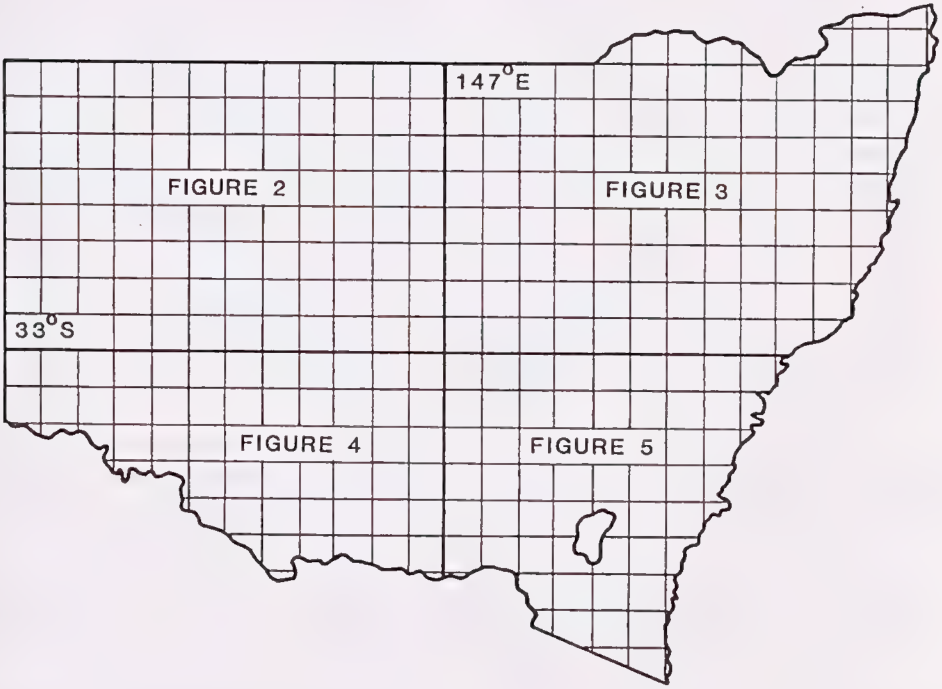


Figure 1. Key to the four index maps of New South Wales showing the 1:100 000 topographic map base grid.

Table 2. Maps relevant to New South Wales Botanical Subdivisions (abbreviations as on map of botanical divisions and subdivisions *Cunninghamia* 2 (1), 145).

Botanical Subdivision	Map number
NSW	1 10 20 24 36 88
NC	19 21 27 28 32 43 44 46 47 49 51 59 77 82 86 87
CC	3 4 6 7 9 12 15 16 21 30 33 48 53 58 75 82 84 85
SC	23 57 58 71 83
NT	27 32 43 45 46 47 49 51 59 77 78 82 86
CT	4 5 21 30 48 50 55 58 63 75
ST	11 13 17 23 26 37 38 39 48 54 55 57 58 63 71 72 73 83 89
NWS	1 27 45 46 47 51 52 53 60 62 70 77 78 82
CWS	2 35 48 50 55 56 63 73 74 75 76
SWS	35 37 38 39 54 55 56 73 74
NWP	2 8 11 27 29 42 45 46 51 53 60 64 65 80f 80g 80h 80j 80k 80m 80n 80o
SWP	1 2 11 35 42 54 64 65 76 80i 80l 81
NFWP	2 29 42 65 80a 80b 80c 80e 80g 80k 81
SFWP	2 22a 22b 22c 22d 22e 22f 22g 22h 22i 42 65 80d 80i 80p 81

Table 3. Map references

The following list of references is arranged alphabetically by author. The number appearing in the left hand column next to the reference is shown in relevant grid squares on Figures 2–5. Factors relating to the description and/or discussion of the following categories of information in the texts with maps are indicated as V-Vegetation, R-Rare plants, Sp-Species list, W-Weeds, Cs-Conservation status/significance, M-Management, F-Fire, S-Soils, Cl-Climate, T-Topography/physiography/landforms, Ge-Geology, Gm-Geomorphology, H-Hydrology/water resources, Fa-Fauna, L-Land Use (past, present, future), Se-Socio-Economics.

1. NSW: Beadle, N.C.W. (1981). The Vegetation of Australia. Cambridge University Press, Cambridge. A black and white vegetation map shows 100 units for the Australian continent. Scale about 1:11 450 000. Text — V, CL, T, Ge, Gm, S.

2. CWS, NWP, SWP, NFWP, SFWP: Beadle, N.C.W. (1948). The vegetation and pastures of western New South Wales with special reference to soil erosion. Government Printer, Sydney. A coloured vegetation map shows 21 units. Scale 1:1 013 760 (1 inch – 16 miles). Text — V, Sp, S, Cl, T, Ge, H.

3. CC: Benson, D.H. (1986). The vegetation of the Gosford and Lake Macquarie 1:100 000 vegetation map sheet. *Cunninghamia* 1 (4): 467–489. A coloured vegetation map showing 12 units, and first published map of the Sydney 1:100 000 Vegetation series. Text — V, T, Ge, R, Cl, L, Gs.

4. CC: Benson, D.H. (1984). Vegetation of the Burragorang area. Unpublished. Royal Botanic Gardens, Sydney. Dyeline vegetation map covers the southern half of 1:100 000 Burragorang map sheet and shows 20 units. Prepared as part of the Sydney 1:100 000 Vegetation series. Text — V, R, Sp, T, Ge.

5. CC: Benson, D.H. (1984). Vegetation of the Wallerawang area. Unpublished. Royal Botanic Gardens, Sydney. Dyeline vegetation map showing 19 units. Prepared as part of the Sydney 1:100 000 Vegetation Series. Text — V, R, S, Cl, T, Ge, L.

6. CC: Benson, D.H. (1985). Vegetation of the Penrith area. Unpublished. Royal Botanic Gardens, Sydney. Dyeline vegetation map showing 20 units. Prepared as part of the Sydney 1:100 000 Vegetation Series. Text — V, Cl, T, Ge.

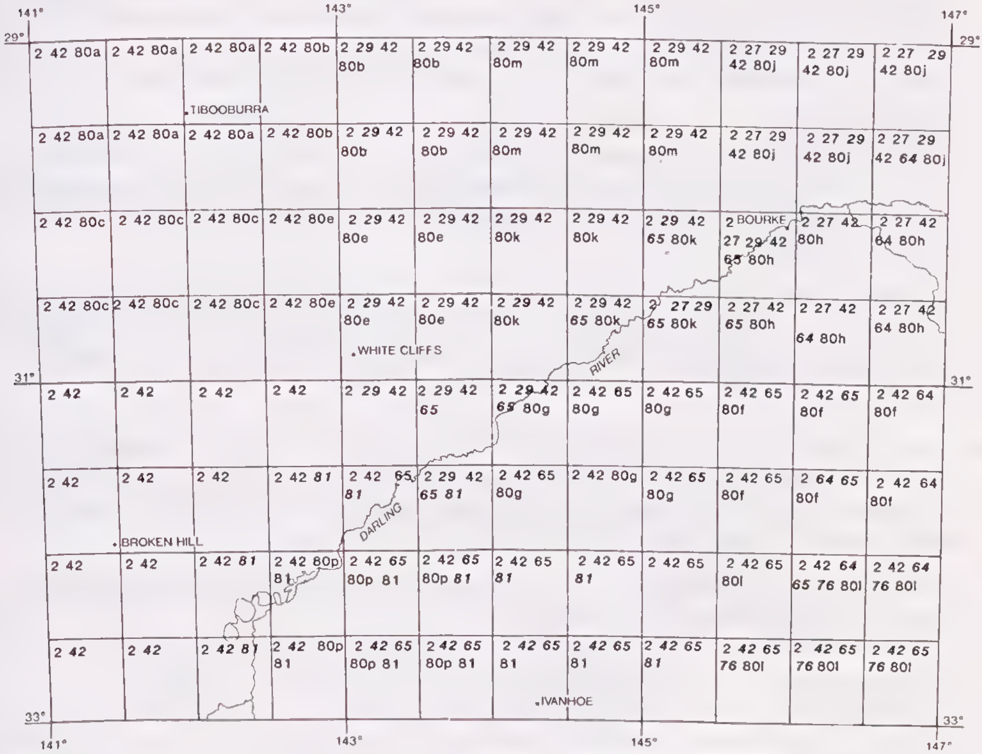
7. CC: Benson, J.S. & Fallding, H. (1981). Vegetation survey of Brisbane Water National Park and environs. *Cunninghamia* 1(1):79 – 113. A coloured vegetation map showing 12 units. Scale 1:50 000. Text — V, R, Sp, F, S, Cl, T, Ge.

8. NWS, CWS, NWP: Biddiscombe, E. F. (1963). A vegetation survey in the Macquarie Region, New South Wales. CSIRO Australia. Division of Plant Industry. Technical Paper 18. A coloured vegetation map shows 11 units. Scale about 1:300 000. Text — V, Sp, Cl, S, T, Ge.

9. CC: Burrows, F. J. (1983). Vegetation structural formations in the Elouera Bushland Natural Park. Elouera Bushland Natural Park Trust, Hornsby. An uncoloured vegetation map (p. 22) shows 5 units. Scale 1:25 000. Text — V, Sp, M, T, Ge, Fa, L.

10. NSW: Carnahan, J. A. (1976). Natural vegetation. In *Atlas of Australian resources.* Second series. Department of National Resources, Canberra. A coloured vegetation map of Australia shows 126 units. Scale 1:6 000 000. See (a) Table 1. Text — V.

11. NWS, CWS, SWP: Chinnick, L.J. & Key, K. H. (1971). Map of soils and of the locust *Chortiocetes terminifera.* CSIRO Australia Division Entomology Technical Paper 12. A three-sheet coloured soils map showing 33 soil units and 3 units of tree density. Scale 1:126 720. Dominants of associated natural



2 42 80a	2 42 80a	2 42 80a	2 42 80b	2 29 42 80b	2 29 42 80b	2 29 42 80m	2 29 42 80m	2 29 42 80m	2 27 29 42 80j	2 27 29 42 80j	2 27 29 42 80j
2 42 80a	2 42 80a	2 42 80a	2 42 80b	2 29 42 80b	2 29 42 80b	2 29 42 80m	2 29 42 80m	2 29 42 80m	2 27 29 42 80j	2 27 29 42 80j	2 27 29 42 64 80j
2 42 80c	2 42 80c	2 42 80c	2 42 80e	2 29 42 80e	2 29 42 80e	2 29 42 80k	2 29 42 80k	2 29 42 65 80k	2 27 29 42 65 80h	2 27 42 80h	2 27 42 64 80h
2 42 80c	2 42 80c	2 42 80c	2 42 80e	2 29 42 80e	2 29 42 80e	2 29 42 80k	2 29 42 65 80k	2 27 29 65 80k	2 27 42 65 80h	2 27 42 64 80h	2 27 42 64 80h
2 42	2 42	2 42	2 42	2 29 42	2 29 42 65	2 29 42 65 80g	2 42 65 80g	2 42 65 80g	2 42 65 80f	2 42 65 80f	2 42 64 80f
2 42	2 42	2 42	2 42 81	2 42 65 81	2 29 42 65 81	2 42 65 80g	2 42 80g	2 42 65 80g	2 42 65 80f	2 64 65 80f	2 42 64 80f
2 42	2 42	2 42 81	2 42 80p 81	2 42 65 80p 81	2 42 65 80p 81	2 42 65 81	2 42 65 81	2 42 65	2 42 65 80l	2 42 64 65 76 80l	2 42 64 76 80l
2 42	2 42	2 42 81	2 42 80p 81	2 42 65 80p 81	2 42 65 80p 81	2 42 65 81	2 42 65 81	2 42 65 81	2 42 65 76 80l	2 42 65 76 80l	2 42 65 76 80l

Figure 2. North-western New South Wales showing the 1:100 000 grid and the vegetation maps (Table 3) available for each grid cell.

vegetation keyed to soil units in Table 1 pp. 10–12. Text — S.

12. CC: Clarke, P. J. & Benson, D. H. (1986). Vegetation survey of Dharug National Park. Unpublished. Royal Botanic Gardens, Sydney. An uncoloured vegetation map shows 21 units. Scale 1:25 000. Text — V, Cs, R, Sp, Cl, Ge, Gm, S, L, W, F.

13. ST: Costin, A. B. (1954). A Study of the ecosystems of the Monaro Region of New South Wales with special reference to soil erosion. Government Printer Sydney. A coloured vegetation map shows 14 units. Scale about 1:400 000. Text — V, Sp, Cl, S, Ge, T, Fa, L.

14. CC: Department of Environment & Planning (formerly New South Wales Planning and Environment Commission) (1979). Illawarra Draft Regional Environmental Plan. Department of Environment Planning, Sydney. Coloured vegetation map shows 9 units. Scale 1:500 000. Text — V, H, T, Ge, Se.

15. CC: Department of Environment & Planning (1983). Brisbane Water estuarine wetlands study. Department of Environment and Planning, Sydney. Figures 4 to 13 show distribution of various wetland communities in the Brisbane Water area in 1954 and 1979. 3 communities are shown. Scale about 1:18 000. Figure 14 shows the distribution of seagrasses in Brisbane Water in 1981. Scale about 1:44 750. Text — V, Fa, Cs, M.

16. CC: Department of Environment & Planning (1984). Sydney Region North West sector. Regional Environmental Study Vol. 2. Map Atlas. Department of Environment and Planning, Sydney. Map 12 is a black and white vegetation map showing 18 floristic units. Map 13 shows vegetation structure with 7 units. Scale about 1:160 000. Vol. 1 describes in detail the north west sector in the Sydney Region context, a resource inventory and analysis and strategic development options.

17. ST: Department of Environment & Planning (1985). Kosciusko regional environmental study (Snowy River) Department of Environment and Planning, Sydney. Uncoloured vegetation map shows 7 units. Scale 1:500 000. Text — V, S; Cl, T, Ge, H, Fa, L, Se.

18. CC, CT: Fallding, H. & Benson, J. S. (1985). Natural vegetation and settlement at Macquarie Pass, Illawarra region, New South Wales. *Cunninghamia* 1(3):285 — 311. Black and white vegetation map shows 17 units. Scale 1:25 000. Text — V, Sp, Cl, S, Ge, T, L.

19. NC: Field, C. D. & Associates & Insearch Ltd. (1983). An investigation of natural areas Kooragang Island, Hunter River. ed. J. Moss. Department of Environment and Planning Sydney, 1983. Black and white vegetation map shows 11 units. Scale about 1:30 300. Text — V, Cs, M, H, Fa.

20. NSW: Forestry Commission of N.S.W. (various dates). Various forest and forest species type maps for N.S.W.

	Map name	**Information on map**	**Scale**
A.	Reserves	Designated forests & timber reserves	1:2 000 000
B.	Forests & forest types	Designated forests & timber reserves. On verso: NSW forest types.	1:4 000 000 coloured

	Map name	Information on map	Scale
C.	Forest species types from Forins	20 forest species units incl. plantations. From Forest Resource Inventory of the State 1971 — 72.Forestry Commission N.S.W. Tech. Paper 28 1976	1:1 000 000 Computer plotted 4 sheet dyeline
D.	Forest structure	Eleven forest structural units incl. plantations, dry lakes & sand ridges. See above for reference.	1:1 000 000 Computer plotted 4 sheet dyeline
E.	Forest species	The 20 units in C above are amalgamated into 11. From FORWOOD Resource panel. See C above for reference.	1:1 000 000 Computer plotted 4 sheet dyeline
#	State forests maps. (formerly project maps)	Designated forests, timber reserves & forestry plantations	1:125 000 coloured
	(# = NC, CC, SC, NT, CT, ST, NSW, SWS, NWP, SWP, SFWP)		
#	Management maps 1:25 000 standard Topographic Map names.	Forest species types including plantations.	1:25 000 dyeline
	(# = NC, CC, SC, NT, CT, ST)		

An up to date catalogue is available from the Forestry Commission of New South Wales.

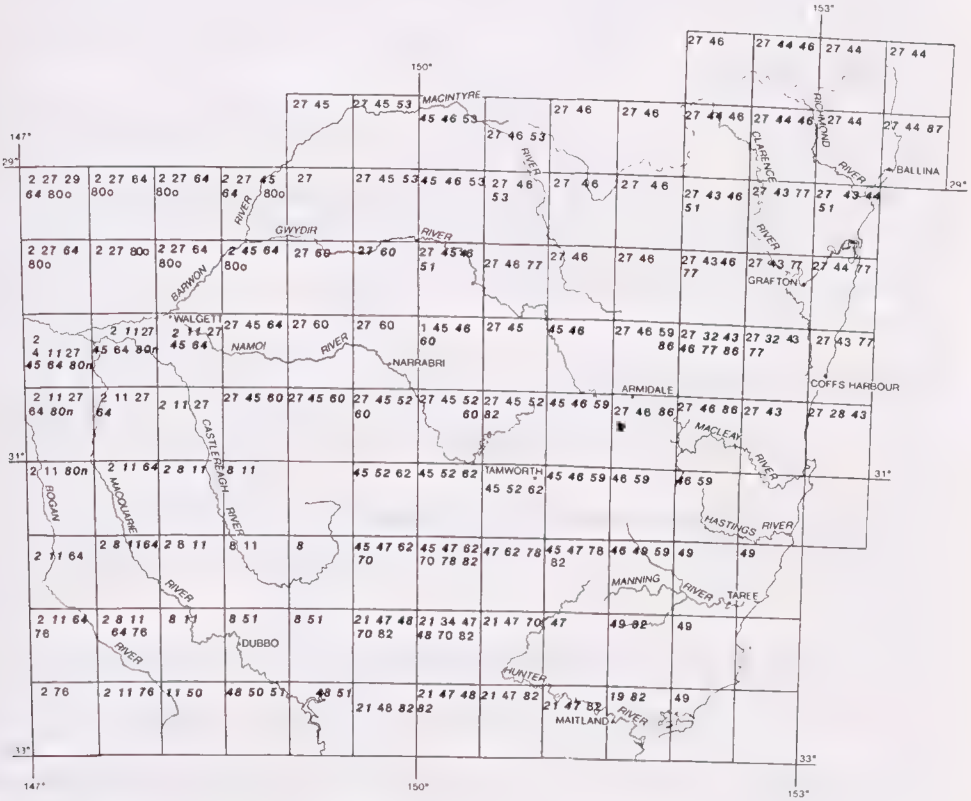


Figure 3. North-eastern New South Wales showing the 1:100 000 grid and the vegetation maps (Table 3) available for each grid cell.

21. NC, CC: Forster, G. R. (1981). Conservation values and vegetational changes Upper Hunter, Ulan and the western coalfields. Department of Environment and Planning. Uncoloured vegetation map shows 10 units. Scale 1:250 000. Text — V, Cs.

22. SFWP: Fox, M.D. (1983). Vegetation of South-Western New South Wales. Unpublished. Royal Botanic Gardens, Sydney. An ongoing project to map the vegetation of western New South Wales. Dyelines. 1:250 000 scale vegetation maps are compiled from 1:100 000 scale vegetation maps. Maps completed are 1:100 000 (a) Bunnerungee – 12 units, (b) Cuthero – 12 units, (c) Lake Victoria – 15 units, (d) Lindsay – 13 units, (e) Mildura – 9 units, (f) Para – 11 units, (g) Popiltah – 14 units, (h) Scotia – 10 units, (i) Wentworth – 12 units.

23. SC: Gunn, R. H., Austin, M.P., Galloway, R. W. & Richardson, D.P. (1978). Land systems of the South Coast study area, New South Wales. In *Land use on the South Coast of New South Wales. A study in methods of acquiring and using information to analyse regional land use options.* Eds Austin, M.P. and Cocks, K.D. Division of Land Use Research, CSIRO, Australia. Coloured land systems map shows 66 units which are keyed to geology, soils and vegetation. Scale 1:150 000. Text is 4 volumes Vol. 1 – General report, Vol. 2 – Biophysical background studies (V + 8 sketch maps of vegetation type distribution, C, Ge, T, S, Fa, H), Vol. 3 – Se, Vol. 4 – L.

24. NSW: Hayden, E. J. (1971). Natural vegetation of New South Wales. In *Atlas of resources of New South Wales.* Department of Industrial Development and Decentralisation of N.S.W. (formerly Department of Decentralisation and Development of N.S.W.) Coloured vegetation map shows 51 units. Scale 1:1 500 000 . This is a vegetation compilation from previously published and unpublished maps.

25. SC: Ingwersen, F. (1976). Vegetation of the Jervis Bay Territory. Department of the Capital Territory Conservation Series 3. Australian Government Publishing Service, Canberra. Two vegetation maps: A coloured vegetation map with inset shows 19 units. Scale 1:25 000 with scale of inset map about 1:7 600. An uncoloured vegetation and land use map on pp. 14–15 shows 11 units. Scale 1:100 000. Text — V, Sp, Cl, T, Ge, F, M, L, W, E. See also *Operculum* 3 (1,2) Vegetation of the Jervis Bay District with special reference to land use and conservation. Map here is a simplified version of the above.

26. ST: Ingwersen, F., Evans, O. & Griffiths, B. (1974). Vegetation of the Ainslie-Majura Reserve. Department of Capital Territory Conservation Series 2. Australian Government Publishing Service, Canberra. An uncoloured vegetation map shows 9 units. Scale about 1:21 170. Text — V, Sp, Cl, S, Se, W, F, L, M.

27. NC, NT, NWS, NWP: Isbell, R. F. (1962). Soils and vegetation of the brigalow lands, Eastern Australia. CSIRO Soils and Land Use Series 43. The distribution of brigalow vegetation is shown by a coloured soils map showing 5 units. Scale about 1:1 500 000. Text — Cl, Ge, L.

28. NC: Jackson, Teece, Chesterman, Willis & Partners. (1983). Arakoon State Recreation Area draft plan of management. Volume 1 scheme of operations. Prepared for National Parks & Wildlife Service. An uncoloured vegetation map opp. p. 12 shows 9 units. Scale about 1:15 000. Text — V, Cl, T, Ge, S, L, M.

29. NFWP, NWP: James, J. W. (1960). Erosion survey of the Paroo-Upper Darling Region. Pt. III. Vegetation and pastures. *Journal of the Soil Conservation Service New South Wales* 10 (3): 185–206. An uncoloured vegetation map (pp. 190–191) shows 10 units. Scale about 1:1 622 000. Text — V.

30. CC: Keith, D. A. & Benson, D. H. (1988). The natural vegetation of the Katoomba 1:100 000 map sheet. *Cunninghamia* 2, 107–143. Vegetation map shows 32 units. Scale 1:100 000. Prepared as part of the Sydney 1:100 000 Vegetation Series. Text — V, R, Sp, Cl, T, Ge.

31. NFWP: Mabutt, J. A., Corbett, J. R., Milthorpe, P. L., Ngethe, J. C., Sullivan, M., Bailey, P. F., Bell, F. C., Hall, L. S., Myers, K. & Parker, B. S. (1974). Lands of the Fowlers Gap-Calindary area New South Wales. Fowlers Gap Arid Zone Research Station, Research Series 4. The University of New South Wales. A coloured land systems map shows 31 units. Scale 1:350 000. Also an uncoloured pasture lands map showing 12 units. Scale about 1:500 000. Text — V, T, S, Ge, Gm, Cl, L, Fa.

32. NC, NT: McArthur, W. M. (1964). Soils and land use in the Dorrigo–Ebor–Tyringham area, New South Wales. CSIRO Soils and land Use Series 6. Vegetation is discussed and related in text to a coloured soils map showing 7 units. Scale is about 1:253 440. Text — Cl, S, V, L.

33. CC: McRae, R. H. D. (1983). Vegetation of Bouddi National Park. Unpublished. Royal Botanic Gardens, Sydney. Dyeline vegetation map shows 20 units. Scale 1:12 500. Text — V, Sp, R, Cs, M, W, F, Cl, S, Ge, Gm.

34. CWS: McRae, R. H. D. & Cooper, M. G. (1985). Vegetation of the Merriwa area, New South Wales. *Cunninghamia* 1 (3): 351–269. A coloured vegetation map shows 17 units. Scale 1:100 000. Text — V, Sp, R, Cs, Cl, Ge, Gm, S, L.

35. CWS, SWS, SWP: Moore, C.W.E. (1953). The vegetation of the south-eastern Riverina, New South Wales. 1. The climax communities, and 2. The disclimax communities. *Australian Journal of Botany* 1 (3): 485–547, 548–567. A coloured vegetation map shows 8 units. Scale about 1:506 880. Text — V, Sp, R, Cl, S, Ge, H.

36. NSW: Moore, R.M. ed. (1970). *Australian Grasslands.* Australian National University Press, Canberra. Three coloured vegetation maps of Australia. Scale 1:12 000 (i) Vegetation of Australia – 24 units, (ii) Grazing Lands of Australia – 13 units, (iii) Pastures of Australia – 6 units. Text — S, V, Fa, M, L, W.

37. ST, SWS: Morland, R. T. (1958–1959). Erosion survey of the Hume catchment area. Parts 2, 3 & 4 vegetation. *Journal of the Soil Conservation Service New South Wales* 14 (4): 293– 326, 15 (1): 66–99 and 15 (2): 72–186. Two coloured vegetation maps. Scale 1:253 440 (i) Climax ecology – 22 units. (ii) Grassland types – 8 units. See also Parts 1 14 (3) 191–255. Text — Cl, S, Ge., Part 4 15 (3) 208–226. Text — L, F., Part 6 16 (1): 5–30. Text — E, M.

38. ST: National Capital Development Corporation (1981). Murrumbidgee River ecological study. Technical Paper 33. Canberra. An uncoloured vegetation map shows 10 units. Scale about 1:25 000. Text — V, R, Fa, S, L, Cs, M.

39. ST: National Capital Development Corporation (1984). The ecological resources of the A.C.T. Technical Paper 42. Canberra. Coloured vegetation map shows 29 units. Scale 1:100 000. Text — V, R, Cs, Fa. Also another map showing sites of ecological interest. Scale about 1:250 000.

40. SFWP: Northcote, K. H. (1951). A pedological survey of the soils occurring at Coomealla, New South Wales. CSIRO Bulletin 264. An uncoloured vegetation map shows 19 units. Scale 1:15 840. Text — Cl, Ge, T, S, V.

41. LHI: Pickard, J. (1985). Vegetation of Lord Howe Island. *Cunninghamia* 1 (2): 133 — 265. A coloured vegetation map shows 25 units. Scale 1:15 840. Text — V, S, Cl, Ge, T, Fa, L.

42. NWP, SWP, NFWP, SFWP Pickard, J. (ms). Vegetation map of North-Western New South Wales. Unpublished. Royal Botanic Gardens, Sydney. Dyeline vegetation map covers the area 27–33° S and 141–147° E and shows 44 units. Scale 1:1 000 000.

43. NC, NT: Premier's Department, Division of Reconstruction and Development, Sydney. (1945). The Clarence Region. A preliminary survey of resources. A broad discussion on forest species is related to a climatic zones map. Also some floristic breakdown in relation to soils. Scale 1:253 440. Text — T, Ge, Cl, S, V, L, Se.

44. NC: ——— (1945). The Richmond–Tweed Region. A preliminary survey of resources. A broad discussion on forest species is related to a climatic zones map. Also some floristic breakdown in relation to soils and geology. Scale 1:253 440. Text — T, Ge, Cl, S, V, L, Se.

45. NT, NWS, NWP: ——— (1950). The Namoi Region. A preliminary survey of resources. Vegetation notes describe 8 main units that are keyable to soils map. Scale 1:633 600. Text — T, Ge, Cl, V, S, E, H, L, Se.

46. NC, NT, NWS: ——— (1951). The New England Region. A preliminary survey of resources. Vegetation notes describe 8 main units with components keyable to a soils map. Scale 1:633 600. Text — T, Ge, Cl, E, H, L, Se.

47. NC, NT, CC, CT, NWS, CWS: ——— (1952). The Upper Hunter Region. A preliminary survey of resources. Vegetation is described in relation to soil

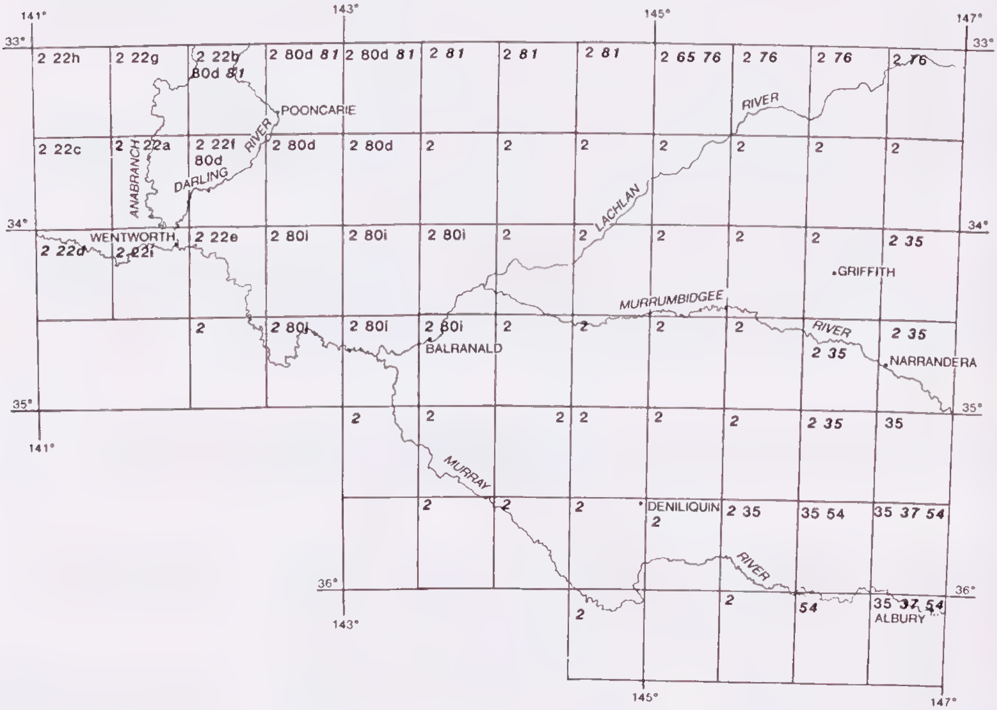


Figure 4. South-western New South Wales showing the 1:100 000 grid and the vegetation maps (Table 3) available for each grid cell.

erosion and proclaimed catchment area maps. Scale 1:1 013 760. Text — T, Ge, Cl, V, S, E, H, L, Se.

48. CC, CT, CWS: ——— (1953). The Mitchell Region. A preliminary survey of resources. Vegetation map shows 22 units. Scale 1:1 013 760. Text T, Ge, Cl, S, E, H, L, Se. Soil Conservation Service of New South Wales District Technical Manuals. (Various authors and dates). Soil Conservation Service of New South Wales. Text of the District Technical Manuals (D.T.M.) includes S, Ge, L, E, V, Cl and maps relating to the above subjects.

49. NC: Cornally, M. J. (1985). Vegetation. In Taree D.T.M. Vegetation map shows 12 units. Scale about 1:625 000.

50. CT, CWS: Dwyer, P.J. (1978). Vegetation. In Orange D.T.M. (D.T.M.). Vegetation map shows 8 units. Scale approximately 1:312 500.

51. CWS: Dwyer, P. J. (1982). Vegetation. In Wellington D.T.M. Vegetation map shows 11 units. Scale about 1:500 000.

52. NWS: Dyson, J. & Marston, D. (1976). Vegetation. In Gunnedah D.T.M. Vegetation map shows 4 units. Scale about 1:417 000.

53. CWS: Johnston, W. H. (1975). Vegetation. In Temora D.T.M. Vegetation map shows 5 units. Scale about 1:330 000.

54. ST, SWS: Johnston, W. H. (1978). Vegetation. In Albury D.T.M. Vegetation map shows 9 units. Scale about 1:500 000.

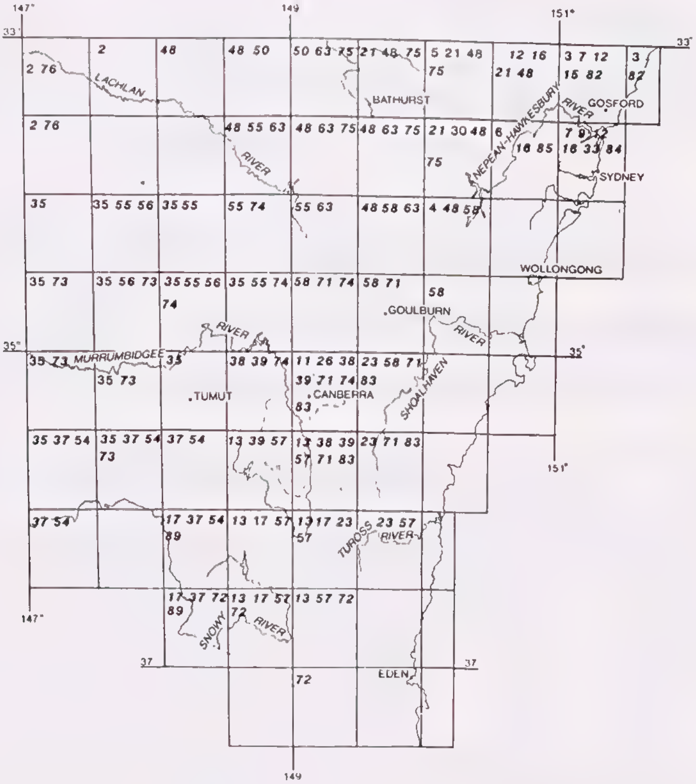


Figure 5. South-eastern New South Wales showing the 1:100 000 grid and the vegetation maps (Table 3) available for each grid cell.

55. CWS: Johnston, W. H. (1982). Vegetation. In Young D.T.M. Vegetation map shows 6 units. Scale about 1:400 000. Map is adopted from Costin (1954).

56. CWS, SWS: Johnston, W.H. (1986). Vegetation. In Cootamundra D.T.M. Vegetation map shows 7 units. Scale about 1:500 000.

57. ST: Keane, P. A. (1977). Vegetation. In Cooma D.T.M. Vegetation map shows 8 units. Scale about 1:400 000. Map is adopted from Costin (1954).

58. ST: Lang, R. D. (1981). Vegetation. In Goulburn D.T.M. Vegetation maps shows 8 units. Scale about 1:470 600.

59. NC, NT: Marston, D. (1976). Vegetation. In Walcha D.T.M. Vegetation map shows 8 units. Scale about 1:500 000.

60. NWS, NWP: Marston, D. (1978). Vegetation. In Narrabri D.T.M. Two vegetation maps: Tree communities map shows 16 units, Grass communities map shows 6 units. Both scales 1:500 000.

61. NWS: Marston, D. (1979). Vegetation. In Tamworth D.T.M. Two vegetation maps: Tree Communities map shows 18 units, Grass communities map shows 4 units. Both scales 1:500 000.

62. NWS: Marston, D. (1980). Vegetation. In Quirindi D.T.M. Two vegetation maps: Tree communities map shows 10 units, grass communities map shows 4 units.

63. CT: More, R. (1976). Vegetation. In Blayney D.T.M. Vegetation map shows 7 units. Scale about 1:312 500.

64. NWP, SWP: Thompson, D. F. (1982). Vegetation. In Nyngan D.T.M. Vegetation map shows 15 units. Scale about 1:500 000.

65. NWP, SWP, NFWP, SFWP: Walker, P.J. & Green, D. R. (1978). Vegetation. In Cobar D.T.M. Vegetation map shows 12 units. Scale about 1:1 333 333.

The following District Technical Manuals give no individual section authors.

66. ST: Braidwood D.T.M. (no date). Vegetation map shows 7 units. Scale about 1:253 440.

67. CWS: Scone D.T.M. (1971). Vegetation map shows 7 units. Scale about 1:253 440.

68. NWS: Inverell D.T.M. (1972). Vegetation map shows 9 units. Scale about 1:443 520.

69. NT, NWS: Barraba D.T.M. (1973). Two vegetation maps: A tree map shows 2 units and a grassland map shows 7 units. Both scales about 1:253 440.

70. CWS: Merriwa D.T.M. (1973). Vegetation map shows 5 units. Scale about 1:294 000.

71. ST: Queanbeyan D.T.M. (1973). Vegetation map shows 10 units. Scale about 1:312 000.

72. ST: South-East District Bombala T.M. (1973). Vegetation map shows 6 units (after Costin, 1954). Scale about 1:253 440.

73. CWS, SWS: Wagga Wagga D.T.M. (1973). Vegetation map shows 6 units (after Moore, 1953). Scale about 1:330 000.

74. ST, CWS, SWS: Yass D.T.M. (1974). Vegetation map shows 6 units. Scale about 1:312 500.

75. CT: Bathurst D.T.M. (1974). Vegetation map shows 8 units. Scale about 1:285 000.

76. CWS: Condobolin D.T.M. (1974). Vegetation map shows 9 units. Scale about 1:770 000.

77. NC: Grafton D.T.M. (1975). Vegetation map shows 8 units. Scale about 1:400 000.

78. NT, CWS: Murrurundi D.T.M. (1975). Vegetation map shows 7 units. Scale about 1:350 000.

79. NWS, NWP: Warialda D.T.M. (1975). Vegetation map shows 7 units. Scale about 1:660 000.

80. NWP, SWP, NFWP, SFWP: Soil Conservation Service of New South Wales (various dates). Land Systems Map Series. All maps are coloured & 1:250 000 scale. Map legends–Ge, T, S, V. Milparinka (1979) 31 units, Urisino (1979) 21 units, Cobham Lake (1980) 38 units, Pooncarie (1980) 21 units, White Cliffs (1980) 42 units, Cobar (1983) 25 units, Barnato (1983) 46 units, Bourke (1983) 30 units, Balranald (1984) 22 units, Enngonia (1984) 30 units, Louth (1984) 47 units, Nymagee (1984) 32 units, Yantabulla (1984) 17 units, Walgett-Nyngan (1985) 12 units, Angledool-Moree (no date) 22 units, Manara (1985) 33 units.

81. SWP: Stannard, M. E. (1963). Erosion survey of the Central East-Darling Region. Part III Vegetation. *Journal of the Soil Conservation Service of New South Wales* 19 (1): 17–28. Vegetation map pp. 22–23 shows 8 units. Scale about 1:1 013 760. Text — V, T in Part I 18 (3) 143–153, S in Part II 18 (4) 173–182 and E in Part IV 19 (2) 69–80.

82. NC, CC, NT, CWS: Story, R. (1963). Part VII. In general report on the lands of the Hunter Valley. CSIRO Land Research Series 8. A coloured vegetation map shows 13 vegetation units and 6 units of grass vegetation. Scale about 1:750 000. Text — V, Sp, Cl, T, S, Ge, Gm.

83. SC, ST Story, R. (1969). Part VII. In lands of the Queanbeyan–Shoalhaven area A.C.T. and N.S.W. CSIRO Land Research Series 24. A coloured vegetation map shows 5 units with further separation of some areas. Scale 1:350 000. Text — V, Sp.

84. CC, CT: Sydney Series 1:25 000 Vegetation Maps. (Various dates and authors). Unpublished. Royal Botanic Gardens, Sydney.Maps are used in compiling the 1:100 000 Vegetation Series maps. Scale 1:25 000. Dyeline. Barallier (Cooper 1983) – 8 units, Ben Bullen (Benson 1983) – 8 units, Bimlow (Keith 1984) – 9 units, Cullen Bullen (Benson 1983) – 12 units, Glen Alice (Benson, 1983) – 5 units, Gospers Mountain (Benson, 1983) – 5 units, Hampton (Keith 1984) – 9 units, Hartley (Keith 1984) – 15 units, Hilltop (Cooper 1983) – 12 units, Jenolan (Keith 1984) – 12 units, Kanangra (Keith 1984) – 10 units, Katoomba (Keith 1984) – 10 units, Kurragong (Benson 1984) – 9 units, Lithgow (Benson 1983) – 11 units, Liverpool (Benson 1984) – 8 units, Mittagong (Cooper & Powrie 1983) – 12 units, Mt Morgan (Benson 1983) – 6 units, Mt Wilson (Keith 1984) – 13 units, Penrith (Benson 1984) – 8 units, Prospect (Benson 1984) – 5 units, Riverstone (Benson 1984) – 9 units, Rock Hill (Benson 1983) – 9 units, Springwood (Benson 1983) – 11 units, Warragamba (Benson 1984) – 7 units, Wilberforce (Benson 1984) – 7 units, Wollangambe (Benson 1983) – 10 units.

Thomas, J. & Benson, D. H. (1985). Vegetation survey of Ku-ring-gai Chase National Park and Muogamarra Nature Reserve. Unpublished. Royal Botanic Gardens, Sydney. Uncoloured dyeline vegetation map shows 22 units. Scale 1:25 000. Text is two reports. 1. Ku-ring-gai Chase National Park — V, Cs, R, Sp, Cl, Ge, Gm, S, L, W, F. 2. Muogamarra Nature Reserve — V, Cs, R, Sp, Cl, Ge, Gm, S, L, W, F.

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86. NC, NT: University of New England, Department of Geography (1965). Preliminary report of geography of Dumaresq Shire for the Council of Dumaresq Shire, Armidale N.S.W. (ed. R. F. Warner). An uncoloured land cover map shows 9 units incl. crops and introduced pastures for 1964. Scale 1:63 360. Text — V, T, Ge, Cl, S, E, L, Se.

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88. NSW: Williams, R. J. (1955). Vegetation regions. In Atlas of Australian Resources. 1st ed. Department of National Development, Canberra. Coloured, pre-settlement vegetation map of Australia shows 35 units. Scale 1:6 000 000. Text — V.

89. ST: Wimbush, D. J. & Costin, A. B. (1973). Vegetation mapping in relation to ecological interpretation and management in the Kosciusko Alpine Area. CSIRO Australia Division of Plant Industry Technical Paper 32. Two coloured vegetation maps. One map of alpine/subalpine area shows 9 vegetation units. Scale 1:31 680. Inset map of general area is after Morland (1952) and shows 12 units. Scale about 1:90 000. Text — V, Cs, L.

Acknowledgments

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Flowering times of plants found in Oxley Park, Tamworth

J.R. Hosking

Abstract

Hosking, J.R. (NSW Agriculture & Fisheries, Agricultural Research Centre, R. M. B. 944, Tamworth, Australia, 2340) 1990. Flowering times of plants found in Oxley Park, Tamworth. Cunninghamia 2(2): 197–216. The vegetation of Oxley Park, Tamworth, N.S.W. (between 31°04′S and 31°07′S and 150°56′E and 150°59′E) was surveyed. A list of plant species and periods over which they flowered has been compiled from January 1984 to December 1985, with some records for other times. In all, 434 species were recorded, 243 being native and 191 exotic.

Introduction

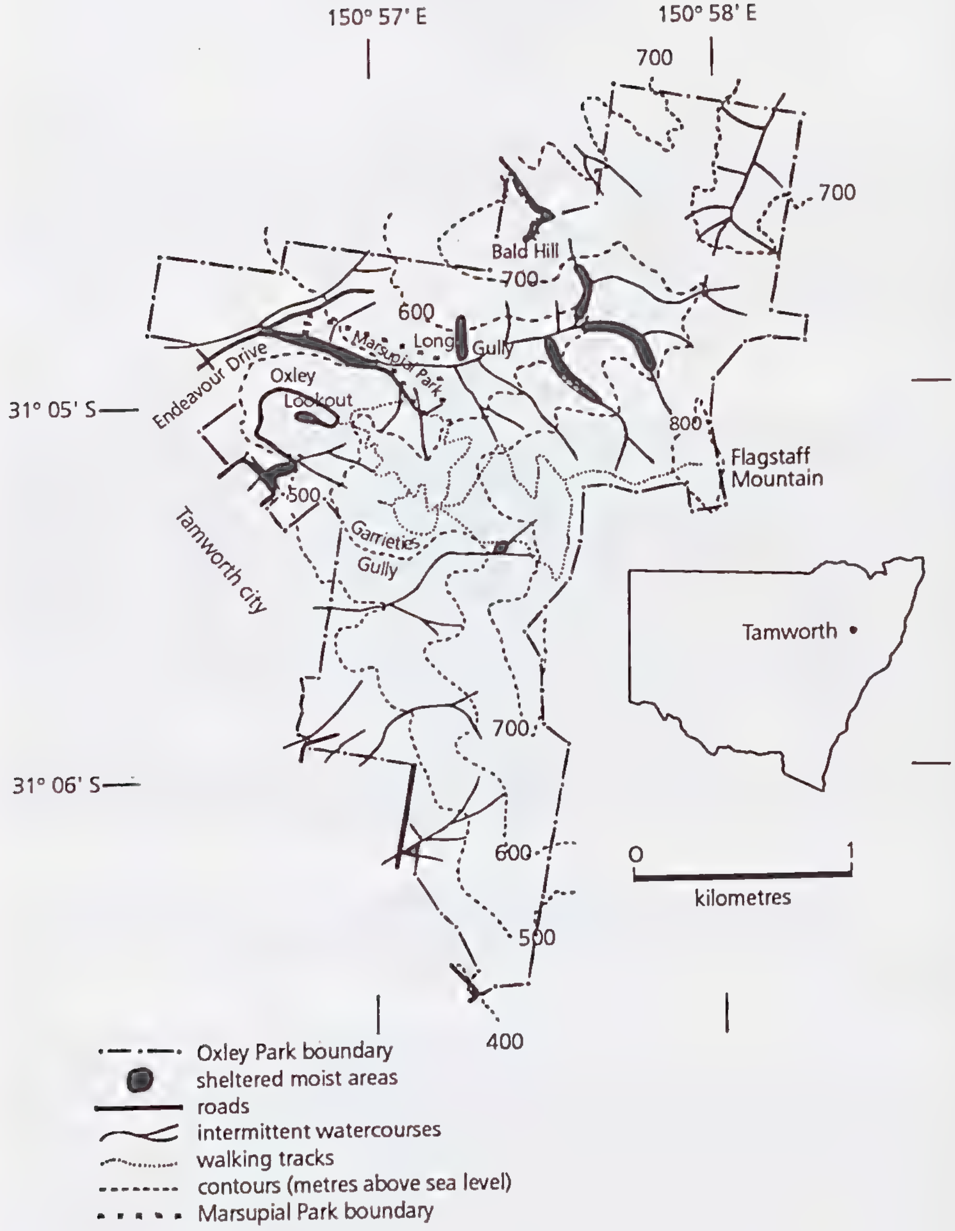
Oxley Park is on the north-eastern edge of Tamworth and covers the hills which form a backdrop to the city. The most frequently visited feature in the Park is Oxley Lookout (31°05′S 150°57′E), an area overlooking Tamworth. The height of the Park varies from 400 m in the south-east corner to 831 m on the top of Flagstaff Mountain. Soil is generally shallow red brown earth. The long-term average rainfall at Tamworth airport is 675.9 mm (Anon. 1972) but rainfall is higher in the Park because of the higher altitude. Approximately 60% of rainfall falls in the summer and 40% in the winter. Temperatures vary from an average minimum of 2.7°C in July to an average maximum of 32.5°C in January (Anon. 1972).

Oxley Park is predominantly an open woodland community dominated by *Eucalyptus albens* (white box), while some of the sheltered gullies have dry rainforest species forming vine thickets. There are also areas of native grassland.

The Park was gazetted as a public reserve in 1888 and since then there have been a number of additions and the area has increased from 372 ha to 521 ha (Map 1). It is held in joint trusteeship by Tamworth City Council and the Lands Department.

Specimens were identified by the National Herbarium of New South Wales. Voucher specimens of most species found in the Park have been lodged at the herbarium of the Agricultural Research Centre, Tamworth and additional specimens are lodged at the National Herbarium of New South Wales, Sydney and the herbarium of The University of New England, Armidale.

Tamworth is in the south-eastern part of the botanical sub-division of New South Wales known as the North Western Slopes and few plant lists are available for this region. Williams (1979) lists plants found in pastures of the North West Slopes, however, it does not include all the species covered in the present work. The most comprehensive list could be extracted from Jacobs and Pickard (1981) but this covers all species found throughout the entire North West Slopes. This sub-division covers a large area with many soil types and climates.



Map 1. Oxley Park showing contours, streams, roadways, walking tracks and sheltered moist areas.

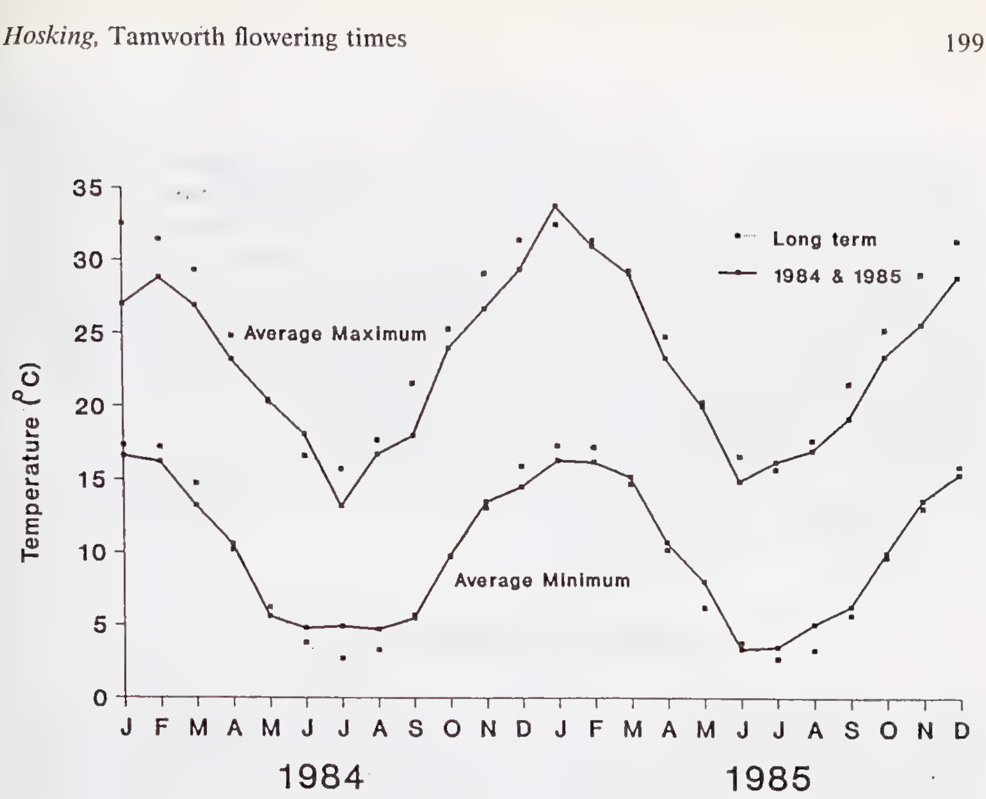


Figure 1. Temperature data for Tamworth airport, New South Wales, approximately 9 km east of Oxley Park. Data for 1984, 1985 (airport records) and long term average (Anon. 1972).

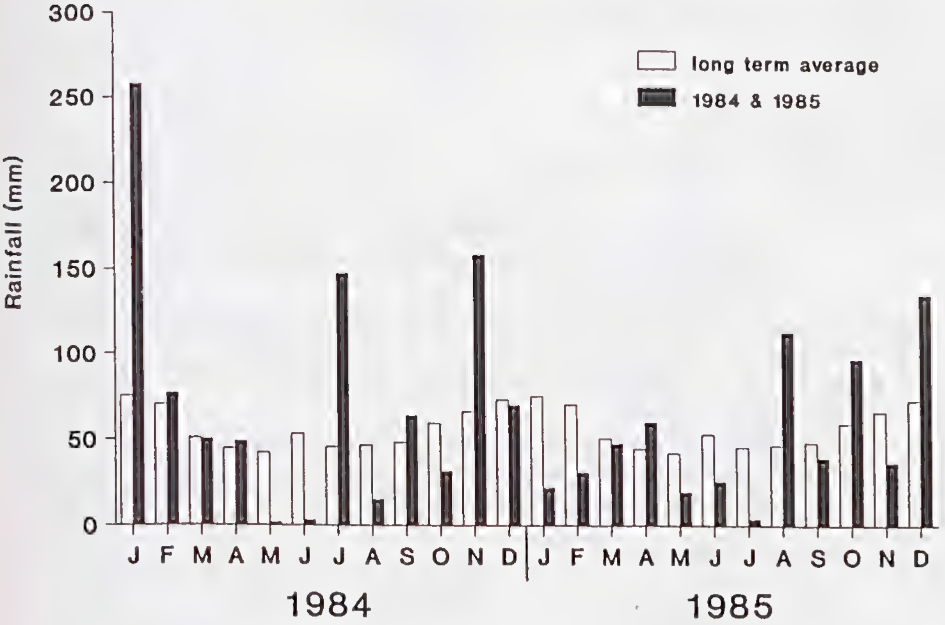


Figure 2. Rainfall data for Tamworth airport, New South Wales, approximately 9 km east of Oxley Park. Data for 1984, 1985 (airport records) and long term average (Anon. 1972).

Methods

The flora list and flowering times were largely compiled between January 1984 and December 1985. Visits to the Park were usually made three times per month, between days 1 and 10, between days 11 and 20 and between days 21 and the end of the month. Not all areas of the Park could be visited on each occasion so the flowering times are conservative. The areas visited the most during this study were along the town boundary, the walking tracks and Long and Garrieties Gullies. Flowering times covered here include all times that each species was found in flower. In many cases most plants of the same species flower over a much shorter period. Flowering times of Pteridophytes cover the time that spores were being produced.

Climatic data, both long-term and from 1984 and 1985, from Tamworth airport, are shown in Figures 1 and 2.

Species list and discussion

A list of species is given in Table 1 and a short description of the vegetation of Oxley Park is included to give some further explanation and to clarify the abundance and distribution of some of the species. Botanical names in the list are from Jacobs and Pickard (1981), alterations to that census by Jacobs and Lapinpuro (1986), volumes of *Flora of Australia* (published by the Australian Government Publishing Service) or recent names supplied by the National Herbarium of New South Wales.

Table 1. Flowering times of plants found in Oxley Park, Tamworth.

Key

Before the species

* indicates an exotic species

! indicates a native species which is probably not, or definitely not, native to this area

Voucher V = vouchers lodged with National Herbarium of New South Wales and the herbarium of the Agricultural Research Centre, Tamworth
= no voucher available

Habitat D = disturbed areas and town edge of Park (includes roadsides, lawns and tracks)
H = high elevations of the Park (above 700 m)
M = many habitats
N = plant rarely found and habitats therefore uncertain
P = plants deliberately introduced to the area and showing no apparent spread (planted in Marsupial Park, as shelter belts or in lawns)
W = moist and wet areas

Abundance C = common
L = locally common
U = uncommon

Frequency (visits) F = area where species occurs was checked frequently
I = area where species occurs was checked infrequently

Flowering times

The letters correspond to the month, commencing with January.
Within the table flowering times are recorded as:

+ = 1984
x = 1985
* = both 1984 & 1985
o = years other than 1984 & 1985

Species	**Voucher Habitat Abundance Frequency (VHAF)**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Park visits during 1984 and 1985		*	*	*	*	*	*	*	*	x	*	*	*
PTERIDOPHYTES													
ADIANTACEAE													
Adiantum aethiopicum	V W C F	*	*	*	*	x	*	*	*	x	*	*	*
1984 and 1985													
PTERIDOPHYTES													
ADIANTACEAE													
Adiantum aethiopicum	V W C F	*	*	*	*	x	*	*	*	x	*	*	*
ASPLENIACEAE													
Asplenium flabellifolium	V W L I	o	o						o		x	x	x
DENNSTAEDTIACEAE													
Pterideum esculentum	V N U I											x	x
SINOPTERIDACEAE													
Cheilanthes distans	V M C F	*	*	+	*		*	+	+	o	x	*	*
Cheilanthes lasiophylla	V M C F	*	+	+	*	*	*	*	+	x	*	*	*
Cheilanthes sieberi	V M C F	*	*	+	*		*	+	+	o	x	*	*
Pellaea falcata var. *falcata*	V W C F	*	*	+	+	*	*	+	+	x	*	*	*
GYMNOSPERMS													
CUPRESSACEAE													
Callitris glaucophylla	V M C F								x	o	*		
**Sabina virginiana*	V D U I				x			x			x		
ZAMIACEAE													
Macrozamia diplomera	V H L I						x	x	x	x	x		
MONOCOTYLEDONS													
ALLIACEAE													
Nothoscordum inodorum	V D U I											x	*
ARECACEAE													
**Phoenix canariensis*	V N U I									o			
COMMELINACEAE													
Commelina cyanea	V W L I	x	x									*	
**Tradescantia albiflora*	V D U I	o	o									x	x
CYPERACEAE													
Carex incomitata	V W C F	*								o	*	*	*

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
Carex inversa	V M C F		+	x						x	*	*	*
Cyperus gracilis	V M C F	*	*	+	x						x	x	*
**Cyperus rotundus*	V D U I			+	+	x						x	x
Cyperus vaginatus	V W C I	+	x				x				+	*	*
Schoenus apogon	V M U I	x									+	x	+
Scleria mackaviensis	V M U I	o	*	+									x
IRIDACEAE													
**Iris germanica*	N U I										+		
JUNCACEAE													
Juncus usitatus	V W C I	+	x									*	*
Luzula meridionalis	V N U I									o	x	x	
LILIACEAE (s. lat.)													
**Aloe saponaria*	V N L I												+
Arthropodium milleflorum	V M C F	*	+	+						o	*	*	*
Arthropodium minus	V M C F									x	*	*	+
**Asparagus officinalis*	V W U I											o	
**Asphodelus fistulosus*	V D C F	*	*	*	+			*	*	x	*	*	*
Bulbine bulbosa	V H C I									o	o	x	+
Dianella laevis	M C F	*	+									*	*
Dianella revoluta	V M C F	x			+	+			o	x	*	*	x
Dichopogon fimbriatus	V M C F	+	+							o	x	*	*
**Myrsiphyllum asparagoides*	V W L I									o			
Thysanotus tuberosus	N U I											o	
Wurmbea biglandulosa	V N L I									o			
ORCHIDACEAE													
Cymbidium canaliculatum	N U I												x
Dipodium punctatum var. *punctatum*	N U F											*	
Microtis unifolia	V N U I											x	
Pterostylis hamata	N U I											o	
PHILESIACEAE													
Eustrephus latifolius	V W C F					o	o	o	+		x	*	*
POACEAE													
Agropyron scabrum var. *scabrum*	V M C F	*	*	+	*	+	+		+	o	*	*	*
!Agrostis avenacea var. *avenacea*	V D U I				+						*	+	x
!Aristida leptopoda	V D L F	*	*	*	*							+	x
Aristida ramosa	V M C F	*	*	*	*	*	*	*			x	*	*
**Avena fatua*	V D C F					x		x	x	x	*	*	*
**Avena ludoviciana*	V D U I										x	+	x
Bothriochloa macra	V M C F	x	*	*	*	*	*	*				*	*
**Briza maxima*	V D L F										*	*	x
**Briza minor*	V D L F										*	*	
**Bromus catharticus*	V D C F	*	*	*	*	+				x	*	*	*
**Bromus molliformis*	V M C F								+	x	*	*	+
**Bromus rubens*	V D L I							x		x			
**Catapodium rigidum*	V M C F									o	*	x	
Chloris acicularis	V D U I	o	+	+							o	*	x
Chloris truncata	V M C F	*	+	+	*	x	x			x	o	*	*
Chloris ventricosa	V M C F	*	*	*	*	*	*				x	*	*

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
Chloris virgata	V D U F	*	*	*	*	*						x	
Cymbopogon refractus	V M C F	*	*	*	*	x	+	x	o		x	*	*
!*Cynodon dactylon*	V D L F	*	*	*	*	*	*	x	x		*	*	*
Danthonia caespitosa	V M U I		+		+	+					x	x	‡
Danthonia linkii var. *linkii*	V M C F	*	+	*	+						+	*	*
Danthonia racemosa var. *racemosa*	V M C F	*	+	+	*			x			*	*	*
Danthonia richardsonii	V M C F	*	+	x	+						x	*	*
Dichanthium sericeum	V M C F	*	*	*	*	*	*	x	+	x	x	*	*
!*Dichanthium setosum*	V D L I	x	o	*	+		o	o			x	*	x
Dichelachne micrantha	V M C F	*	+	+	*	x				x	*	*	*
Digitaria brownii	V M C F	*	*	+	*	*		x				x	*
**Digitaria ciliaris*	V D L I	o	+	x	x	x						x	x
Digitaria divaricatissima	V M C F	*	*	*	*	x						*	*
**Echinochloa colona*	D U I				+								
**Echinochloa crus-galli*	D U I												x
Echinopogon intermedius	V W C F	*	o	x								*	*
**Ehrharta erecta*	V W L I	o								o	o	x	x
**Eleusine tristachya*	V D C F	*	*	*	*	x					x	*	*
Enneapogon nigricans	V M C F	*	*	*	*	x	x	x			x	*	*
**Eragrostis cilianensis*	V D C F	*	*	*	*							x	x
Eragrostis leptostachya	V M C F	*	*	*	*							*	*
Eragrostis parviflora	V N U I												x
Eriochloa pseudoacrotricha	V D C F	*	*	*	*	+						*	*
!*Heteropogon contortus*	V D L I	x	+	*	*		o	o					x
**Hordeum leporinum*	V D U F									x	*	*	x
**Hyparrhenia hirta*	V D U F	o	o									*	*
**Lamarckia aurea*	V D L I									o	x	x	
Leptochloa ciliolata	V W C F	*	*	+	*	x		+				x	*
**Lolium perenne*	D U I												x
**Lolium rigidum*	V D U F										*	*	*
**Lophochloa cristata*	V M C F									x	*	*	o
Microlaena stipoides var. *stipoides*	V W C I	x	x	+	*		+					x	*
Panicum decompositum	V D C F	*	*	x	*	+	x				x	*	*
Panicum effusum	V M C F	x	+	+									*
Paspalidium aversum	V M U I	o	o		x								o
Paspalidium gracile	V M C F	*	*	*	*	x	*			x	x	*	*
**Paspalum dilatatum*	V D L F	*	*	*	*	*	*	x				*	*
**Pennisetum clandestinum*	V D U I												x
**Pennisetum villosum*	V D U F	+	*	*	*	*					x	x	x
**Poa annua*	V D U I							x	x	x	x	*	
Poa labillardieri	V M C F									o	*	*	*
**Sorghum halepense*	V D C F	*	*	*	*	*	*	x				*	*
Sorghum leiocladum	V M U I	x										*	*
Sporobolus caroli	N U I												
Sporobolus creber	V M C F	*	*	*	*	*	*			x	x	*	*
Stipa aristiglumis	V D U I		+	x							x		x
Stipa nodosa	M C F	*	*	x	x	x	x	x	o	o	x	x	x
Stipa scabra subsp. *scabra*	V M C F	x	*	+	*	x	x	x		x	*	*	*
Stipa setacea	V M U I		+								o	x	x
Stipa verticillata	V M C F	*	*	*	x		+		x	o		*	*
Themeda australis	V M C F	*	*	+	+	+					x	*	*
Themeda avenacea	N U I											+	

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
Tragus australianus	V D C F	+	*	*	*	x	x						x
**Triticum aestivum*	V D U I	+									x		
**Urochloa panicoides*	V D U I	o	x	x	x	x	x					x	x
**Vulpia myuros*	V M C F	x							o	x	*	*	x
TYPHACEAE													
Typha domingensis	V W U I	x	x										x
XANTHORRHOEACEAE													
Lomandra filiformis subsp. *filiformis*	V N U F									x	*	x	
Lomandra longifolia	V M U I									o	+	*	
Lomandra multiflora subsp. *multiflora*	V M U I									o	x	x	
Xanthorrhoea glauca subsp. *angustifolia*	V W L I									o			
DICOTYLEDONS													
ACANTHACEAE													
Brunoniella australis	V M C F	*	+	+						o	*	*	*
Rostellularia adscendens subsp. *adscendens*	V M C F	*	*	*	*	x	*		o	o	x	*	*
AMARANTHACEAE													
**Alternanthera pungens*	V D C F	*	*	*	*	*	+				x	*	*
**Amaranthus hybridus*	V D C F	*	*	*	*	+	+					x	x
!Amaranthus mitchellii	D U I			+									
**Amaranthus viridis*	V D U I	o											
**Gomphrena celosioides*	V D U I	*	x	x	x	x		x				+	x
ANACARDIACEAE													
**Schinus areira.*	V M C F	*	*	*	*	*	*	*	*	x	*	*	*
APIACEAE													
**Ammi majus.*	V D C F	*	*	*	x		*	+			+	*	*
**Apium leptophyllum*	M C F	*	*	*	*	+					x	*	*
Daucus glochidiatus	V M C F	+	+							o	*	*	x
**Foeniculum vulgare*	V D L F	*	*	*	*	x	x					*	*
Hydrocotyle laxiflora	V M C F	*	+	+	+						x	x	*
APOCYNACEAE													
**Nerium oleander*	V N U I	*	o	o	o							*	x
Parsonsia eucalyptophylla	N U I												
Parsonsia lanceolata	V M C F	x	*	*				o					
ASLEPIADACEAE													
**Araujia hortorum*	V D U I												x
**Gomphocarpus fruticosus*	V M C F	*	*	*	x							*	*
Gymnema pleiadenium	V W L F											x	*
**Tweedia coerulea*	V M C F	x	x	+	x						x	*	x
ASTERACEAE													
**Arctotheca calendula*	V D L F	+							o	x	*	*	x
**Bidens pilosa*	V M C F	*	*	*	*	*	*	*	*	x	*	*	*
**Bidens subalternans*	V D U F			+	*	x							
**Calendula officinalis*	V D U I											x	x
Calotis lappulacea	V M C F	*	*	*	*	*	x		o	x	*	*	*
**Carduus tenuiflorus*	V M C F										*	*	
**Carthamus lanatus*	V D C F	*	*	*								+	*

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
Cassinia quinquefaria	V M C F	*	*	*	*	*	*						
**Centaurea calcitrapa*	D U I	o	o	o									
**Centaurea melitensis*	V M C F	x		+	*		+	+	+		x	*	*
**Centaurea solstitialis*	V M C F	*	*	*	*	*	*		+		*	*	*
**Cirsium vulgare*	V M C F	*	*	*	x				x	x	*	*	*
**Conyza albida*	V D C F	*	*	*	*	*	*	*	+				*
**Conyza bilbaoana*	V D U I			x									
**Conyza bonariensis*	V M C F	*	*	*	*	*	*	x	x	x	*	*	*
!Cotula australis	V D L I										x	*	
Cymbonotus lawsonianus	V M C F		+			x	x	x	*	x	*	*	
**Dimorphotheca pluvialis*	V D U F									x	*	*	x
Glossogyne tenuifolia	V M C F	x	*	+	*	x	x				x	*	*
**Gnaphalium coarctatum*	D U I	+	+	+	+							+	*
Gnaphalium gymnocephalum	V H U F	*	*	*	*	+	+	+	+		+	*	*
Gnaphalium involucratum	V M U I	o		o	+		x	x	x	*	x	*	*
Gnaphalium sphaericum	V M C F	*	*	*	*	+	+	+	+		+	+	*
**Hedypnois rhagodioloides* subsp. *cretica*	V D U I	+								o	*	*	*
**Helianthus annuus*	V D L F	*	*	*	*	*	*					+	o
Helichrysum apiculatum	V M C F	*	*	*	*	*	*	*	+	o	x	*	*
Helichrysum bracteatum	N U I	+	+										o
**Hypochoeris glabra*	V M C F	x								x	*	*	+
**Hypochoeris radicata*	V M C F	*	*	+	+		+			o	x	*	*
Isoetopsis graminifolia	V N U I									o			
**Lactuca saligna*	V M L F	x	*	*	*	+							x
**Lactuca serriola*	V M C F	*	*	*	+							o	x
Lagenifera stipitata	V W L I											x	x
!Leptorhynchos panaetioides	V D U I	o	x	x	x	x						x	x
Leptorhynchos squamatus	V N U I	x		+							*	*	x
Olearia viscidula	V H C I									o	*		
Olearia sp. G (aff. *elliptica*)	V M C F	+	+	*	*	o							
**Schkuhria pinnata* var. *abrotanoides*	V D C F	*	*	*	*	*	*	x			*	*	*
Senecio hispidulus var. *dissectus*	V M C F	*	*	+	x		*	x	+	x	*	*	*
Senecio lautus subsp. *dissectifolius*	V M C F	*	+	+	*	*	*	*	*	x	*	*	*
Senecio quadridentatus	V M C F	*	*	*	*	*	x	x		x	*	*	*
Sigesbeckia microcephala	V M C F	*	*	*	*	x	*			o	*	*	*
**Silybum marianum*	V D L F										*	*	*
**Soliva pterosperma*	V D L F										*	*	
**Sonchus oleraceus*	V M C F	*	*	*	+	+	x	*	x	x	*	*	*
Stuartina hamata	V N U I									o			
**Tagetes minuta*	V D U F			x	x	*	*						
**Taraxacum officinale*	V D U I	+			x	*	x	x	x	x	x	x	x
**Tragopogon porrifolius*	V D L F									o	x	*	*
Triptilodiscus pygmaeus	V M L I									x	x		
Vittadinia muelleri	V M C F	*	+	*	*	x				x	x	*	*
Vittadinia sulcata	V M C F	*	+	*	*	x	*		o	x	*	*	*
**Xanthium occidentale*	V D U F			*	x								
**Xanthium spinosum*	D U I	o	+										

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
BIGNONIACEAE													
**Clytostoma calystegioides*	V P U I										x		
**Jacaranda acutifolia*	V P U F	o	o	o							*	*	
Pandorea pandorana	V M C F						o	+	*	x	*		x
BORAGINACEAE													
**Amsinckia calycina*	V D U I									o	o		
Buglossoides arvense	V D L F							*	+	x		*	
Cynoglossum australe var. *australe*	M U I	o							o	x		o	o
Cynoglossum suaveolens	V M U I									o	o		x
**Echium plantagineum*	V M C F	*	*	*	*	o	*	+	*	x	*	*	*
**Heliotropium amplexicaule*	V D L F	+	*	x	*	x					x	*	x
BRASSICACEAE													
**Capsella bursa-pastoris*	V D C F	+	+		+	*	x	x	*	x	*	x	x
**Coronopus didymus*	V D U I											x	x
**Hirschfeldia incana*	V D C F	*	*	*	*	x	*	x	x	x	*	*	*
**Lepidium africanum*	V D C F	*	*	*	*	*	x	x	x	x	*	*	*
**Lepidium bonariense*	V D U I	o											
**Rapistrum rugosum*	V D C F	o	*	*	*	+	+	*	*	o	*	*	*
**Sisymbrium irio*	D U I								o				
**Sisymbrium officinale*	V D U I											x	x
**Sisymbrium orientale*	V D U I			+	+	+				o	x	*	
CACTACEAE													
**Opuntia aurantiaca*	M C F	*	*	+								+	*
**Opuntia stricta* var. *stricta*	M C I											o	x
CAMPANULACEAE													
Wahlenbergia spp.	M C F	*	*	*	*	*	*	x	*	x	*	*	*
Wahlenbergia gracilis	V M C F	x	x	x	x	x	x	x	x	x	x	x	*
Wahlenbergia planiflora subsp. *longipilis*	V N U I							+	+	o		x	x
Wahlenbergia stricta subsp. *stricta*	V H L I	x			x	x					+	*	+
CAPPARIDACEAE													
!Capparis mitchellii	M U F												
CAPRIFOLIACEAE													
Sambucus australasica	V W U I												
**Viburnum tinus*	V P U I					o	o	o	o	o			
CARYOPHYLLACEAE													
**Cerastium glomeratum*	V M C F								+	x	*	*	x
**Paronychia brasiliana*	V D C F	*	o	+							x	*	x
**Petrorhagia nanteuilii*	V M C F	*	+	+						o	*	*	*
**Polycarpon tetraphyllum*	V M C F	*	+								x	*	*
Stellaria angustifolia	W U I								o	o	x	x	o
**Stellaria media*	V W C I	+						+	x	x	x	x	
CELASTRACEAE													
Maytenus cunninghamii	V M C F	x	*		+								*

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
CHENOPODIACEAE													
!Atriplex semibaccata	V D U I			x	x	x		x		x		x	
**Chenopodium album*	V D U I	+	+	*	*								
**Chenopodium ambrosioides*	V D U I		o	o	o	o	o	o					
!Chenopodium desertorum	V D U I												x
Chenopodium pumilio	V D U I	+	+	+	x								
Einadia nutans subsp. *nutans*	V M U I	*	+	+	+		x					x	*
Einadia polygonoides	M C F	*	*	+	*	x					x	*	x
Einadia trigonos subsp. *stellulata*	V M C F	*	*	x	*							o	*
!Maireana microphylla	V N U I					o	o	o					
!Salsola kali var. *kali*	V D C F	*	*	*	*	x	x				x	x	x
CONVOLVULACEAE													
Convolvulus erubescens	V M C F	*	*	*	*	x				o	*	*	*
Dichondra repens	V M C F	x									*	*	+
Evolvulus alsinoides var. *decumbens*	V M U I	o	+	+						o			*
**Ipomoea cairica*	V D L F	x	x	*	*	*						+	*
CRASSULACEAE													
**Bryophyllum daigremontianum x tubiflorum*	V W L I									o			
Crassula sieberiana	V M C F	*	+	+	+		+		x	x	*	*	*
DILLENIACEAE													
Hibbertia acicularis	V M L F									o	x	*	x
Hibbertia obtusifolia	V N U I										o		
EPACRIDACEAE													
Melichrus urceolatus	V H U I					o	o	o	x	x			
EUPHORBIACEAE													
Breynia oblongifolia	V W C F	x	*	+	x		*	+	+	x		*	*
Chamaesyce dallachyana	V D C F	*	*	*	*	*	x				+	*	*
Croton phebalioides	V W L I											x	*
Euphorbia eremophila	V M C F	*	+	x	*		x			o		*	*
**Euphorbia peplus*	V D U I				o		o		x			x	x
Phyllanthus subcrenulatus	V N U I	o	o									x	
Phyllanthus virgatus	V N U I												x
Poranthera microphylla	V H C I		+							x	+	x	o
FABACEAE													
!Acacia baileyana	P U I						o	o	o	o			
Acacia deanei subsp. *deanei*	V M C F	*	*	*	*	+	+	+	*	x	x	x	*
Acacia decora	V M C F							+	*	x	*		
Acacia implexa	V M L I	o											x
Acacia neriifolia	V N U I								o	o	x		
Acacia paradoxa	V M L I								o	x	*		
Cassia coronilloides	V M U F	*	+			o					+	*	*
Cassia eremophila var. *zygophylla*	V M L I									*	x		
Desmodium brachypodum	V M C F	*	*	*	x	x					x	*	*
Desmodium varians	V M U I	+	+	+									x

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
Glycine clandestina var. *sericea*	V M C F	+	+	x		x	x		+	x	*	*	+
Glycine tomentella s. lat.	V M C F	*	*	*	*	x			o	o	x	*	*
Hardenbergia violacea	V M U F							*	*	x	*	*	
Hovea lanceolata	V W L I								o	o			
Indigofera adesmiifolia	V M C F						x		*	x	*	*	
**Lathyrus odoratus*	V D U I										x	x	x
Lotus australis	V H C I	+	+		x						o	x	x
**Medicago lupulina*	V D U I											x	x
**Medicago minima*	V M C F		+	+	+	+		*	*	x	*	*	*
**Medicago orbicularis*	V D U I		+								*	x	
**Medicago polymorpha* var. *vulgaris*	V D C F	+	*	*	*	+	x	*	x	*	*	*	
**Medicago sativa*	V D U I	+	*										
**Melilotus albus*	V D C F	x	x	*	*	*	x				x	+	x
**Melilotus indicus*	V D C F	o	x						+		*	*	*
Rhynchosia minima	V M C F		+	*								+	*
Senna barclayana	V M C F	*	*	x								*	*
**Senna pendula* var. *glabrata*	V P U I			+	*	x						x	
Swainsona galegifolia	V M C F	*	*	*	*	x	*	*	*	x	*	*	*
Swainsona monticola	V H L I									x	+	x	
Tephrosia brachyodon	V M L F	*	+	+							x	+	*
**Trifolium angustifolium*	V D U I											x	
**Trifolium arvense*	V M C F	*	+							o	*	*	*
**Trifolium campestre*	V M C F	+		+	+				+	x	*	*	*
**Trifolium glomeratum*	V D C F	+								x	*	*	x
**Trifolium repens*	V D U I	o										x	x
**Vicia monantha* subsp. *triflora*	V D L F	o						o	o	x	*	x	
**Wisteria sinensis*	V P U I	*	x							x	x	+	
FUMARIACEAE													
**Fumaria capreolata* subsp. *capreolata*	V D C F					x	x	x	x	x	x	*	x
**Fumaria muralis* subsp. *muralis*	V D U I								x		x	x	
GENTIANACEAE													
**Centaurium erythraea*	V M C F	*	*	*	*		+	+		x	+	*	*
GERANIACEAE													
Erodium cicutarium	V D U I										x	x	
Erodium crinitum	V M C F	+	+		+				o	x	x	*	x
**Geranium molle* subsp. *molle*	V D L I										o		
Geranium solanderi var. *solanderi*	V M C F	*	*	*	*		x			x	*	*	*
**Pelargonium x hortorum*	V D U I										x	*	x
GOODENIACEAE													
Goodenia glabra	V M C F	*	+	+						o	x	*	*
Goodenia pinnatifida	V M C F										x	*	*
Velleia paradoxa	V M L F	x									*	*	x
HALORAGACEAE													
Haloragis serra	V W C F	*	*	+	+		+					x	*

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
HYPERICACEAE													
Hypericum gramineum	V M C F	*	+	+	*					x	*	*	*
LAMIACEAE													
Ajuga australis	V M C F	*	+	+		o	x		o	o	+	*	*
**Lamium amplexicaule*	D U I				+		+		x		x	*	
**Marrubium vulgare*	V M U F	+	*	+	x	x		x	*	x	*	*	*
Mentha satureioides	V M L I					x	x						*
Mentha sp. (aff. *diemenica*)	V N U I												*
Plectranthus parviflorus	V W U I											x	x
**Salvia reflexa*	V D U I	o	o	o	o	o						x	x
**Salvia verbenaca*	V D L F	o	+	+	*	x				x	*	*	*
Scutellaria humilis	V M C F	*	+		x					x	o	x	*
LOBELIACEAE													
!Pratia concolor	V D U I	+	+	+	+						x		x
Pratia purpurascens	V W L F	x	o	+	*	*	x				x	*	*
LORANTHACEAE													
Amyema miquelii	V M C F	o	*	*	x								
Dendrophthoe vitellina	V M C F										x	*	*
Lysiana subfalcata subsp. *subfalcata*	V M C F	x	*	*	x	x	x	x	x				
MALVACEAE													
Abutilon oxycarpum var. *oxycarpum*	V W L I	o										x	x
Abutilon tubulosum	V M C F	*	*	*	*	+	+				*	*	*
Hibiscus sturtii var. *sturtii*	V M C I	*		+									
**Malva parviflora L.*	D U I	+	+							o	x	x	x
Malvastrum americanum	V M C F	*	*	*	*							+	*
**Modiola caroliniana*	V D U I											+	+
Sida corrugata	V M C F	*	+	*	*						x	x	*
Sida cunninghamii	V M U I	*	o		x	x				o		x	x
MELIACEAE													
!Melia azedarach var. *australasica*	V D U F										*	*	
MORACEAE													
Ficus rubiginosa	V W C F	x	x								*	x	*
MYOPORACEAE													
Myoporum debile	V N U I	o											
Myoporum montanum	V M C F		+		*	*	x	*	*	x	+		
MYRTACEAE													
Angophora floribunda	V M L F	+											
!Callistemon salignus	V P U I										o		
!Callistemon viminalis	V P U I								o	o	o	o	
Eucalyptus albens	V M C F			o	*	*	*	*	*	x	*		x
Eucalyptus blakelyi	V M L I											+	
!Eucalyptus sideroxylon	V P U I					o	o	o	x				
!Melaleuca armillaris	V P U I							o	o	o	o		
NYCTAGINACEAE													
Boerhavia dominii	V M C F	*	*	*	*							*	*

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
**Bougainvillea spectablis*	V P U I	x	x	x	x	x	x	x	x	x	x	*	x
OLEACEAE													
Jasminum lineare	V M C F	*	+	x							x	*	*
**Jasminum mesnyi*	V D L F					o	o	*	*	x	x	x	x
Jasminum suavissimum	V M C F	x										*	*
**Ligustrum lucidum*	V M C F	*										o	*
**Ligustrum sinense*	V W U I											x	+
Notelaea microcarpa var. *microcarpa*	V M C F									x	x	x	x
**Olea europaea*	V M L I	x										o	*
ONAGRACEAE													
Epilobium billardierianum subsp. *cinereum*	V M C F	*	*	*	x		+					*	*
**Oenothera affinis*	V D L F	+	x	*	+						*	*	*
OXALIDACEAE													
Oxalis exilis	V M C F	*	*	*	*	x	x		x	x	*	*	*
**Oxalis pes-caprae*	V D U F					+		*	*	x	x		
PAPAVERACEAE													
**Argemone ochroleuca* subsp. *ochroleuca*	V D C F	+	+	+	+	+	+		+	o	*	x	x
**Papaver hybridum*	V M U I									o	x	x	o
**Papaver somniferum* subsp. *setigerum*	V N U F								o		x	*	x
PHYTOLACCACEAE													
**Phytolacca octandra*	N U I	+	+			o	+		+			o	+
PITTOSPORACEAE													
Bursaria spinosa	V M C F	+	+	+	+		+	*	*	x	*	*	*
Pittosporum phillyreoides	V M L I									x	*		
PLANTAGINACEAE													
Plantago debilis	V M C F	*	*	*	*	*				x	*	*	*
**Plantago lanceolata*	V D C F	*	*	*	*	*		x	x	x	*	*	*
PLUMBAGINACEAE													
**Plumbago auriculata*	V D U I	o	o	o	o	o							x
POLYGONACEAE													
**Emex australis*	V D U I									x	x		x
!Persicaria lapathifolia	V D U F											x	x
**Polygonum aviculare*	V D C F	*	*	*	*	*	x	x			x	x	*
Rumex brownii	V M C F	*	*	*	*	+		x	x	x	*	*	*
**Rumex crispus*	V D U I	x	*								+	+	x
PORTULACACEAE													
!Portulaca oleracea	V D L F	+	*	*	*								x
PRIMULACEAE													
**Anagallis arvensis* red-flowered form	V M C F	*	+	x	x				x	x	*	*	*
**Anagallis arvensis* blue-flowered form	V M C F				+				*	x	*	*	*
PROTEACEAE													
!Grevillea robusta	V M U F											*	x

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
RANUNCULACEAE													
Clematis glycinoides var. *glycinoides*	V M C F									x	*	*	o
Clematis microphylla var. *microphylla*	V M C F							+	*	x			
Ranunculus lappaceus	V H U I					o				o			
Ranunculus sessiliflorus var. *sessiliflorus*	V W C I									o	x	*	
ROSACEAE (s. lat.)													
Acaena novae-zelandiae	V H U I									o		x	
Acaena ovina s. str.	V H L I									o		x	x
**Cotoneaster glaucophyllus*	V D C F											x	+
**Cotoneaster ? glaucophyllus*	V D C F											*	x
**Malus* X *domestica*	V D U I										x		
**Photinia serratifolia*	V D U I										x		
**Prunus armeniaca*	D U I												
**Prunus cerasifera*	V D U I								x	x			
**Prunus persica*	V D U I									x			
**Pyracantha angustifolia*	V D U I											x	x
**Pyracantha crenulata*	V D U I											*	
**Rosa rubiginosa*	V D U I											*	
Rubus parvifolius	V W C F	o										*	+
**Spiraea cantoniensis* var. *lanceolata*	V P U I					o		o	x	x	x		
RUBIACEAE													
Asperula conferta	V M C F						x		o	x	*	*	*
Canthium odoratum	V M C I											o	x
**Galium aparine*	V M C F	+							x	x	*	*	o
Galium gaudichaudii	V H U I											x	
Galium migrans	V M C F	*	*	+	+	x	*		x	x	*	*	*
**Galium murale*	V W L I										x	x	
**Sherardia arvensis*	V H L I										o	x	x
RUTACEAE													
**Citrus limonia* s. lat.	D U I												
SANTALACEAE													
Exocarpos cupressiformis	V M U I		+	+	x		x	+	+				
SAPINDACEAE													
Alectryon forsythii	V W L I		x				+	+	+	o	*	*	+
**Cardiospermum grandiflorum*	V D U F	x	x	*	*	x	x	x			*	*	*
Dodonaea viscosa subsp. *angustifolia*	V M C F					*	*	*	*				
SCROPHULARIACEAE													
**Antirrhinum orontium*	V M U I	+				o			o	o	o	x	x
**Linaria arvensis*	V M U I								o	x	x	x	
**Verbascum thapsus*	N U I												
**Verbascum virgatum*	V M C F	*	*	x	o						*	*	*
**Veronica arvensis*	V M L I									x	x	x	
**Veronica persica*	V D U I										x		
Veronica plebeia	V M U I	+			x					o	x	x	x

Species	(VHAF)	J	F	M	A	M	J	J	A	S	O	N	D
SIMAROUBACEAE													
**Ailanthus altissima*	V W L I											x	
SOLANACEAE													
**Cestrum parqui*	V W L F	x	x	x	x	x	x				x	*	*
**Datura ferox*	V D U I				o	o							x
**Datura stramonium*	V D U I		*	o	o	o						x	x
**Lycium ferocissimum*	V D U I				x	x	x			x			x
**Petunia axillaris*	V D U I	o								o	o	o	o
Solanum cinereum	M U I	+							o	x	o	o	
**Solanum nigrum* subsp. *nigrum*	M U I	+	*	+	*	o					o	x	x
Solanum parvifolium	V M C F	*	*	+	*	o	x			x	*	*	*
**Solanum pseudocapsicum*	V W U I											x	x
STACKHOUSIACEAE													
Stackhousia monogyna	V M L I							x	x	x	*	*	
Stackhousia viminea	V N U I									o			
STERCULIACEAE													
Brachychiton populneus	V M C I	o											x
THYMELAEACEAE													
Pimelea curviflora var. *divergens*	V M C F	*	+	+	*	*	x		+	o	x		*
Pimelea linifolia subsp. *linifolia*	V N U I									o			
Pimelea micrantha	V N U I				o	x							
Pimelea strigosa	V M C F	o	x	+	o			+			*	*	*
URTICACEAE													
**Parietaria diffusa*	V W U I											x	x
Urtica incisa	V M C F	*	*	*	*	x	x	x	x	x	*	*	*
VALERIANACEAE													
**Centranthus ruber*	V W L F	o	o									*	x
VERBENACEAE													
**Lantana montevidensis*	V D L F	*	+	*	*	*	x	x	x	x	*	*	x
Oncinocalyx betchei	V M C F	*	+								o	*	*
**Verbena bonariensis*	V D C F	*	*	*	*	*	*				x	*	*
Verbena officinalis	V M C F	*	*	*	*	*	*		+	x	*	*	*
**Verbena tenuisecta*	V D L I	o	o	x	x	o	x		x		x	*	x
VIOLACEAE													
**Viola odorata*	V D U I									x			
**Viola tricolor*	D U I											x	
VISCACEAE													
Notothixos cornifolius	N U I					o						o	
VITACEAE													
Cayratia clematidea	V W L I	*	x										*
Cissus opaca	V M C F	*	*	*	x								*
ZYGOPHYLLACEAE													
!Tribulus terrestris	V D L F	*	*	*	*								x

Oxley Park is predominantly an open woodland community dominated by *Eucalyptus albens* (white box) with smaller areas of grassland and vine thickets.

Apart from white box other tree species include *Callitris glaucophylla* (white cypress pine) mainly along the western side of the Park, *Angophora floribunda* (rough-barked apple) scattered throughout the Park, *Eucalyptus blakelyi* (blakely's red gum) in Long Gully behind the Marsupial Park and *Brachychiton populneus* (kurrajong) scattered throughout the Park. Some species, such as *Canthium odoratum* (iamboto) and *Notelaea microcarpa* var. *microcarpa* (native olive), grow as small trees in open areas and as large trees in sheltered gullies. In gullies shaded from the sun for most of the day there are a number of species more commonly found in rainforests; these include *Ficus rubiginosa* (rusty fig), *Alectryon forsythii* (ravine bird's eye) and *Croton phebalioides.*

The shrub layer is dominated by *Olearia* sp. G (aff. *elliptica*), *Olearia viscidula*, *Dodonaea viscosa* subsp. *angustifolia* (broad-leaf hopbush) and *Acacia decora* (western golden wattle). Many other shrubs are also present including *Cassinia quinquefaria*, *Maytenus cunninghamii*, *Breynia oblongifolia*, *Acacia deanei* subsp. *deanei*, *Acacia implexa*, *Acacia neriifolia*, *Acacia paradoxa*, *Cassia eremophila* var. *zygophylla*, *Cassia coronilloides*, *Hovea lanceolata*, *Indigofera adesmiifolia*, *Abutilon tubulosum*, *Myoporum montanum*, *Bursaria spinosa*, *Pittosporum phillyreoides* and *Exocarpos cupressiformis.*

There is a great diversity of grasses in the Park, with most species flowering and seeding in summer. *Aristida ramosa* (purple wiregrass) is particularly common. A number of native species appear to have been introduced to the Park accidentally. For example, *Aristida leptopoda* is only found on, and alongside, the track between the Marsupial Park and Oxley Lookout and may have been introduced in soil used to topdress the path. *Dicanthium setosum* appears to have been introduced to the same area, as well as along Endeavour Drive. *Heteropogon contortus* is not found elsewhere in the district and the only known localities in the Park are alongside the same track and alongside roads in the Park.

Some of the more common vines include *Myrsiphyllum asparagoides* (a naturalised exotic species), *Eustrephus latifolius*, *Parsonsia eucalyptophylla*, *Gymnema pleiadenum*, *Pandorea pandorana*, *Convolvulus erubescens*, *Glycine clandestina* var. *sericea* and *Glycine tomentella*, *Hardenbergia violacea*, *Clematis glycinoides* var. *glycinoides*, *Clematis microphylla* var. *microphylla*, *Cayratia clematidea* and *Cissus opaca*. *Gymnema pleiadenium*, an uncommon species, usually found in dry rainforest, is abundant in the lower portion of a gully which runs approximately north west from Flagstaff Mountain into Long Gully.

Four mistletoes are present in the Park; *Amyema miquelii* (box mistletoe) found on *Eucalyptus albens* is most abundant around the edges of the Park, *Dendrophthoe vitellina* (long-flower mistletoe) most commonly seen on *Brachychiton populneus* and *Angophora floribunda* (but also found on *Dodonaea viscosa* subsp. *angustifolia* and *Schinus areira*) is also a common species, *Lysiana subfalcata* var. *subfalcata* (northern mistletoe) is frequently found on a number of shrub species (*Maytenus cunninghamia*, *Acacia deanei* subsp. *deanei*, *Notelaea microcarpa* var. *microcarpa*, *Bursaria spinosa*, *Alectryon forsythii* and *Exocarpos cupressiformis*) and *Notothixos cornifolius* is occasionally found on *Brachychiton populneus*. *Exocarpos cuppressiformis* is also a hemiparasite on the roots of other plants and can be found scattered through the Park.

There are 24 native species which are not, or probably not, native to the Park. Some of these have been deliberately planted and have shown no sign of spreading, these include *Acacia baileyana*, two *Callistemon* species, *Eucalyptus sideroxylon* and *Melaleuca armillaris*. Two are garden escapes, *Melia azedarach* var. *australasica* and *Grevillea robusta*, the former species confined to roadways and the latter scattered in very low numbers throughout the Park. A number of species have been introduced in material used for roadmaking or path construction and for levelling or planting of lawns and are largely confined to these disturbed areas. Some of these have been mentioned in the grass section above and others include *Cynodon dactylon*, *Amaranthus mitchellii*, *Cotula australis*, *Leptorhynchos panaetioides*, *Atriplex semibaccata*, *Chenopodium desertorum*, *Salsola kali* var. *kali*, *Pratia concolor*, *Persicaria lapathifolia*, *Portulacca oleracea* and *Tribulus terrestris*.

Large numbers of exotic species are naturalised in the Park, many are garden escapes while others have been introduced by grazing animals, rubbish dumping and vehicles as well as in soil for tracks and roadworks. *Opuntia aurantiaca* (tiger pear) is a low growing spiny cactus which is found on the edge of the Park nearest town and the north east portion of the Park. *Opuntia stricta* var. *stricta* (common pest pear), another cactus species, has spread throughout the Park. *Ligustrum lucidum* (broad-leaf privet) is a widespread and frequent tree while *Olea europaea* (european olive) and *Ailanthus altissima* (tree-of-heaven) are frequent in some parts of the Park. *Myrsiphyllum asparagoides* (bridal creeper) is locally frequent and appears to be spreading in Long Gully from the town boundary to the eastern side of the Marsupial Park and in the gully crossed by the road to Oxley Lookout. Most of the introduced species are only frequent along the town boundary of the Park, however, a few species such as *Schinus areira* (pepper tree), *Tweedia coerulea* (tweedia), *Cirsium vulgare* (spear thistle), *Centaurium erythraea* (common centaury), *Opuntia stricta* var. *stricta* and *Centranthus ruber* (red valerian) can be encountered throughout the Park.

Two species, *Dicanthium setosum* and *Macrozamia diplomera*, are listed in *Rare or Threatened Australian Plants* (Briggs and Leigh 1988). A survey of the Park, in February 1990, revealed over 1000 plants of each species. *D. setosum* is listed as having a range greater than 100 km, a vulnerable species, conserved in Carnavon National Park but no information is available on the adequacy of reservation. Around 1000 plants were present between the Marsupial Park and the Lookout alongside the walking track and approximately 100 plants occured alongside Endeavour Drive near the entrance to Oxley Park. Both localities would suggest that this species has been introduced to the Park. Some clumps of *D. setosum* were over 20 cm diameter. *Macrozamia diplomera* is listed as having a range greater than 100 km, a rare species, conserved in Warrumbungle National Park but no information is available on the adequacy of reservation. *M. diplomera* occurs in two areas within the Park; about 700 plants were present on the southern side of Bald Hill and about 350 plants occurred on a south facing slope of Flagstaff Mountain alongside the walking track.

New species are being continually introduced to the area. Some of these will only survive for a few years and some will become a permanent part of the flora. One species which became established during this study was *Hyparrhenia hirta* (coolatai grass), it first appeared along Endeavour Drive in November 1984. Another species which was found on the town edge of the Park on one occasion only was *Araujia hortorum*.

A number of species are only present for short periods in certain areas, or are in areas only visited infrequently (for example *Phoenix canariensis*), so the full extent of their flowering period is not recorded. Some, such as *Isoetopsis* *graminifolia* and *Stuartina hamata* are inconspicuous annuals and this has resulted in few records of flowering times. The species mix and areas of occurrence vary from year to year, some are very common following drought years, others are only common in wet years. *Senecio lautus* subsp. *dissectifolius* (variable groundsel) was particularly common in September 1981 following a number of dry years. *Centranthus ruber* is an example of one which is usually confined to moist gullies but can be more widespread in years of high summer rainfall.

Plants found in Oxley Park are typical of those found in the Tamworth area so this flora list will be of particular value to many pollen allergy sufferers. In the past Tamworth medical practitioners and others have had to rely on lists of plants known to occur at Armidale and in Sydney, or on the coast, to correlate allergies with suspected plant species.

Botanists and agriculturalists studying distributions of plant species will also find the list of use. For example, lists of species of the same family present in an area are important to those involved with biological control of weeds, as this knowledge can be used to determine which native plants are likely to be exposed to biological agents introduced for control of other members of the same family. These native plants can then be tested to determine if the introduced biological control agents are likely to have any adverse effect on native species. There are many ways in which this study could be expanded in the future. The major field not covered in this study is plant frequencies over time. This could be studied by means of a number of permanent transects spread through various habitats in the Park. Studies could also be undertaken to define times when plants germinate, growth times to flowering and records of flowering times obtained during this study could be extended.

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Common plants and soil salinity in the Lower Boro area, Southern Tablelands, New South Wales

P.G. Kodela and D.A. Foster

Abstract

Kodela, P.G. & D.A. Foster (School of Geography, University of NSW, Kensington, Australia 2033) 1990. Common plants and soil salinity in the Lower Boro area, Southern Tablelands, New South Wales. Cunninghamia 2(2): 217–222. Over 130 vascular plant species were recorded from the Lower Boro area of New South Wales. Pastures cover much of the landscape, with eucalypt forests and woodlands remaining mainly on hillslopes and steeper ridges. Dryland salinity, associated with clearing of the native vegetation for grazing, occurs on alluvial flats along several watercourses, and on gentle hillslopes. Salt-tolerant species are identified in the survey.

The study area

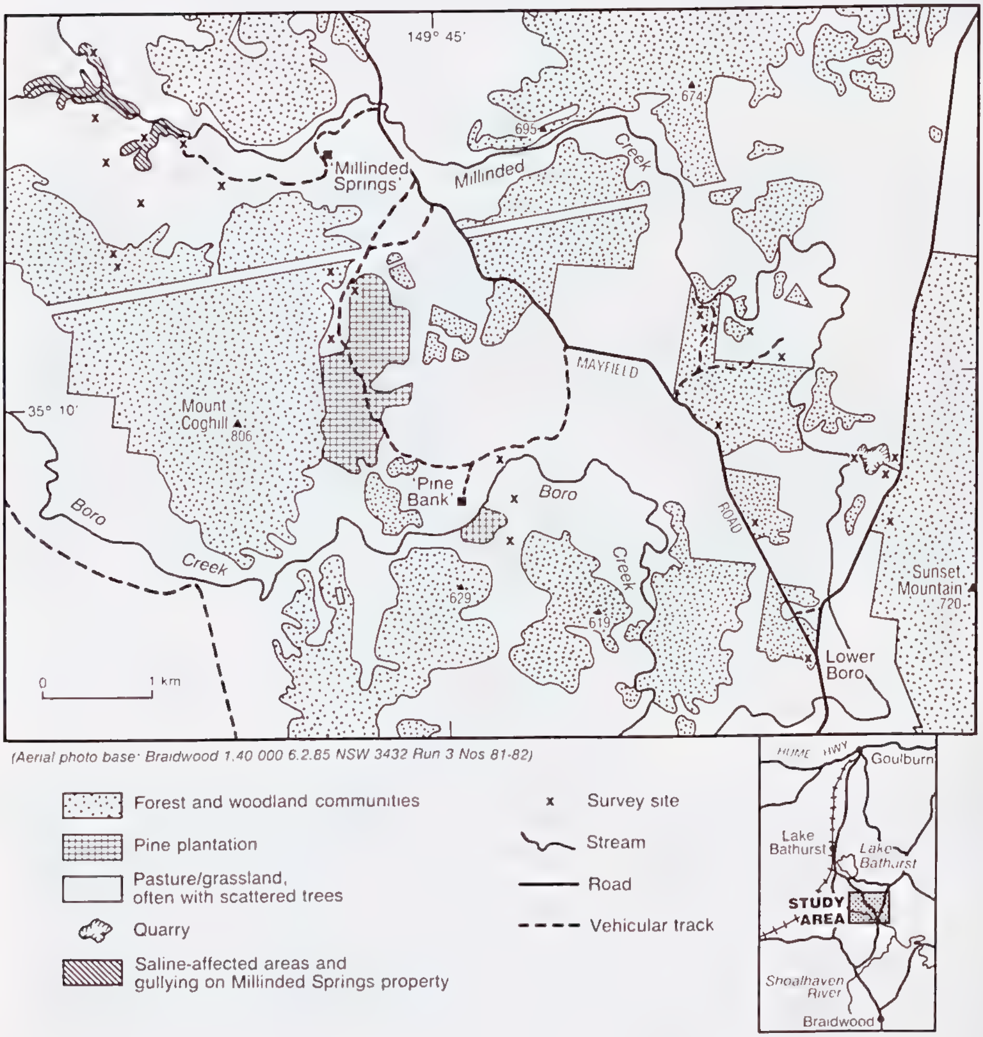
Lower Boro is located about 30 km north of Braidwood on the Southern Tablelands of New South Wales (approximately 35°10′S, 149°45′E, see Map 1). A temperate subhumid climate prevails, with a mean annual rainfall of 709 mm recorded for Braidwood. Braidwood experiences mean daily maximum temperatures of 25.7°C in January to 11.9°C in July, and mean daily minima of 12.1°C in January to –0.1°C in July (Bureau of Meteorology, 1975). The geology, topography and soils of the area are described in detail by Gunn et al. (1969), Felton and Huleatt (1977) and Soil Conservation Service of NSW (undated). Solodic soils (yellow massive earths) have developed on Tertiary alluvial deposits in the gently undulating lowlands, while yellow podzolics (texture-contrast soils) and solodic soils are found on the undulating to rolling terrain of folded Silurian and Ordovician sedimentary rocks and probably Devonian age granodiorite. Local hilly areas have lithosols (skeletal soils) on steep slopes and crests. Quaternary alluvium, with various soil types, occurs in the valley floors of tributaries to the Upper Shoalhaven River.

Vegetation

Previous studies

Vegetation in the region is more closely associated with water relationships and climatic conditions than with rock type or soil (Gunn et al., 1969). Species' distributions and plant growth are influenced by exposure to frosts, heat and dry westerly winds. Vegetation structure and composition are influenced by local climatic conditions that vary with altitude, aspect and topography.

Pryor (1938, 1954), Costin (1954), Story (1969), Burbidge and Gray (1970) and the Soil Conservation Service of NSW (undated) provide early accounts of the Southern Tableland's flora and plant communities. They describe dry sclerophyll forests as occurring on the upper slopes and ridges (hilly terrain), and savannah woodland on the lower slopes and valley floors. Eucalypt forest communities contain associations of *Eucalyptus rossii*, *E. mannifera*, *E. dives* and *E. macrorhyncha*. *E. rubida* can be found mixed with these species on cooler aspects, while *E. sieberi* often occurs on drier, stony crests and upper slopes. Savannah woodland may be thinned dry sclerophyll forest containing the above species, or occur naturally in cool areas on footslopes and valley floors with major species including *E. bridgesiana*, *E. melliodora*, *E. rubida* and *E. blakelyi*. Groundcover in forests and woodlands varies with mixed heath (sclerophyllous shrubs) and herbs. Communities of *E. pauciflora* and *Poa* spp. occur in colder areas. Grasslands were originally found mainly on river flats or frost pockets, but have since increased in area from clearing of forests and



(Aerial photo base: Braidwood 1:40 000 6.2.85 NSW 3432 Run 3 Nos 81-82)

Map 1. Study area showing location of sampling sites.

woodlands (Soil Conservation Service of NSW, undated).

Present survey

A plant survey of the Lower Boro area was undertaken to provide an inventory of vascular plant species, and identify species tolerant of saline soils. Field observations were made during mid-January 1989. Appendix 1 lists vascular plant species observed at various sites (see Map 1), and ground traversed between sites. Descriptions of vegetation structure follow the classification of Specht (1981).

Natural grasslands and improved pastures cover much of the land suitable for agriculture. Within pastures there are scattered individual or patches of trees and shrubs, damp soaks with sedges, and bare erosional scars. Pastures often merge with low open-woodlands to woodlands where clearing of the understorey allows grazing.

Shrub-dominated communities occur in pastures, or form the understorey of woodlands. Heathland/open-heathland/low heathland is common on rocky ridges, while slightly taller heathland/scrub formations are found along the banks of watercourses. *Melaleuca parvistaminea* and *Kunzea parvifolia* are dominant species near creeks and drainage lines, while shrubby species of Epacridaceae, *Hakea sericea*, *Allocasuarina paludosa* and *Leptospermum* are more common on drier slopes and ridges.

Eucalypt open-forest to low open-forest formations occur mainly on the hillslopes. In more exposed and semi-cleared areas woodlands/low woodlands prevail. *Eucalyptus dives* and *E. rossii* are common trees throughout the region. Small trees preferring the alluvial flats in the lowlands include *E. aggregata* and *E. melliodora*. *E. amplifolia* occurs on the cool lowlands and at higher elevations as a low tree with several stems. Many of the eucalypt species have a mallee habit in more exposed situations or as a response to fire damage and clearing (Soil Conservation Service of NSW, undated). Trees must be tolerant of fire, and in the broad valley lowlands to cold air drainage and frosts. *Allocasuarina littoralis* is common in the understorey of open-forests as well as dominating regrowth stands at the edges of eucalypt forests. Forest and woodland stands have highly variable understoreys. On dry exposed ridges and steeper slopes there are scattered low shrubs and herbs, with many rock outcrops. In more protected areas, and where deeper soils occur, there are shrub layers, or scattered medium-tall shrubs to small trees. However, human disturbance has left many forest stands with open understoreys and herb-dominated groundcovers, often with deep litter layers. Herb-dominated groundcovers also occur naturally in lowland woodlands due to the cold climatic conditions. *Acacia decurrens* is common in disturbed areas forming monospecific stands with grass understorey near and amongst the pine plantations at 'Pine Bank'.

Dryland salinity and associated vegetation denudation and gully erosion occurs at 'Millinded Springs' where the Soil Conservation Service is currently undertaking a rehabilitation program. Low available potassium may be a key factor limiting plant growth in these areas (Melville pers. comm.; Hood 1989). *Eucalyptus aggregata* and *E. melliodora* appear to tolerate the salt-affected sediments that result from saline seepage. Other species surviving along these watercourses are indicated in Appendix 1. Some of these species may be suitable for stabilising bare saline areas that are highly susceptible to erosion.

At 'Pine Bank' *Pinus radiata* is planted on slopes and near gullies to help arrest salinity and associated erosion problems. Although *Melaleuca parvistaminea* appears to be a promising shrub for stabilising creek banks in the area it often forms dense thickets that may limit stock access to water. Problems with erosion around shrub roots and the formation of small islands may also occur (property owner pers. comm.).

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Appendix 1

Vascular plant species recorded from Lower Boro.

Nomenclature follows Jacobs & Pickard (1981) and Jacobs & Lapinpuro (1986). Habitat information is provided in code as follows: I-eucalypt forests and woodlands, II-heathland (often in pastures), III-pastures and wasteland, IV-salt-affected areas, V-near stream in protected valley, VI-CSIRO Forestry & Research experimental trial plantation at 'Pine Bank', established 1979. * indicates introduced taxa.

PTERIDOPHYTA
DENNSTAEDIACEAE
Pteridium esculentum I, III, V

ADIANTACEAE
Cheilanthes sp. I, III

GYMNOSPERMAE
PINACEAE
**Pinus radiata* III, IV, plantations

ANGIOSPERMAE-DICOTYLEDONEAE
APIACEAE
**Eryngium rostratum* III
Hydrocotyle laxiflora I, III

ASTERACEAE
Cassinia aculeata I, III
**Centaurea calcitrapa* III
**Cirsium vulgare* III
Gnaphalium sphearicum I, III
Helichrysum apiculatum III
H. bracteatum III
H. diosmifolium IV
**Hypochoeris radicata* I, III
Lagenifera sp. I
Pseudognaphalium luteoalbum III
**Tolpis umbellata* III
Vittadinia muelleri III

BORAGINACEAE
**Echium plantagineum* III

CAMPANULACEAE
Wahlenbergia spp. I, III

CARYOPHYLLACEAE
**Paronychia brasiliana* III
**Spergularia rubra* III, IV

CASUARINACEAE
Allocasuarina littoralis I, III
A. paludosa I, II

CONVOLVULACEAE
Convolvulus erubescens II, III

DILLENIACEAE
Hibbertia acicularis I
H. obtusifolia I, II, III

EPACRIDACEAE
Acrotriche serrulata III
Astroloma humifusum IV
Brachyloma daphnoides I
Lissanthe strigosa II, III
Melichrus urceolatus II, III

EUPHORBIACEAE
Poranthera microphylla I, III

FABACEAE

FABOIDEAE
Glycine sp. I
Hardenbergia violacea I
Jacksonia scoparia I, III
Kennedia prostrata I
Mirbelia platylobioides I
Pultenaea scabra I
P. subspicata I
**Trifolium* spp. III

MIMOSOIDEAE
Acacia brownei II
A. buxifolia I
A. decurrens I, III, V
A. irrorata subsp. *irrorata* I, III, IV
A. terminalis I

GENTIANACEAE
**Centaurium erythraea* III

GOODENIACEAE
Goodenia bellidifolia I, II, III
G. hederacea I, II

HALORAGACEAE
Gonocarpus sp. I
Myriophyllum propinquum III

LAMIACEAE
Mentha diemenica III

LAURACEAE
Cassytha pubescens I

LOBELIACEAE
Pratia pedunculata III

LOGANACEAE
Mitrasacme polymorpha I, III

MYRTACEAE
Eucalyptus aggregata IV
E. amplifolia I, IV
E. dives I
E. globoidea I
E. globulus subsp. *bicostata* VI

E. globulus subsp. *globulus* VI
E. laevopinea VI
E. macrorhyncha subsp. *macrorhyncha* I
E. mannifera I, III
E. melliodora I, IV
E. obliqua VI
E. olsenii VI
E. rossii I
E. rubida I
E. sieberi I, VI
E. viminalis V
Kunzea parvifolia I, II, III
Leptospermum brevipes (variant) II
L. multicaule I
L. myrtifolium II, III
Melaleuca parvistaminea I, II, III, IV, V

OXALIDACEAE
Oxalis corniculata I, III

PLANTAGINACEAE
**Plantago coronopus* III, IV

POLYGALACEAE
Comesperma volubile I

POLYGONACEAE
**Acetosella vulgaris* III

PRIMULARIACEAE
**Anagallis arvensis* III

PROTEACEAE
Banksia marginata I, III
B. paludosa I
B. spinulosa I
Hakea dactyloides I, III
H. decurrens I
H. sericea I, II, III
sopogon prostratus I
Lomatia ilicifolia I
Persoonia linearis I
P. mollis subsp. *livens*

ROSACEAE
Acaena ovina III
**Rosa rubiginosa* III
Rubus parvifolius I

RUBIACEAE
Galium sp. III
Opercularia aspera I

RUTACEAE
Philotheca salsolifolia I

SANTALACEAE
Exocarpos cupressiformis III

SCROPHULARIACEAE
Veronica arvensis III
V. plebeia I, III

SIMAROUBACEAE
**Ailanthus altissima* III

SOLANACEAE
Solanum aviculare V

STYLIDIACEAE
Stylidium graminifolium I, II, III

VIOLACEAE
Viola hederacea I, III

ANGIOSPERMAE-
MONOCOTYLEDONEAE

CYPERACEAE
Eleocharis acuta III, IV
Lepidosperma laterale I
L. urophorum I
Schoenus apogon III

HAEMODORACEAE
Haemodorum planifolium I, II

IRIDACEAE
Patersonia glabrata I

JUNCACEAE
Juncus australis III, IV
J. planifolius III

LILIACEAE
Dianella sp. I

POACEAE
Agrostis avenacea III, IV
Aristida ramosa III
Chionochloa pallida III
Cynodon dactylon III, IV
Danthonia carphoides III
D. monticola III
D. racemosa III
**Eleusine tristachya* I, III
**Eragrostis mexicana* III, IV
**Hordeum leporinum* III
**Lolium perenne* III, IV
Microlaena stipoides III
**Phalaris aquatica* III
Poa sp. I, III
**Polypogon monspeliensis* III, IV
Sporobolus creber III
Stipa mollis I, III, IV
S. scabra subsp. *falcata* III
Themeda australis I, III

XANTHORRHOEACEAE
Lomandra glauca I
L. longifolia I, V
L. obliqua I
Xanthorrhoea resinosa subsp. *concava* I, II, III

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The natural vegetation of Bents Basin State Recreation Area

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Abstract

Benson, D.H., Thomas, J., & Burkitt, J. (National Herbarium of New South Wales. Royal Botanic Gardens. Sydney, Australia. 2000) 1990. The natural vegetation of Bents Basin State Recreation Area. Cunninghamia 2(2): 223–262.* The natural vegetation of Bents Basin State Recreation Area (S.R.A.) (lat. 33°56′S, long. 150°37′E) on the Nepean River west of Sydney is described and mapped from air photos and ground survey. The S.R.A. covers 391 ha with 25 plant communities related to geology (sandstone, shale, alluvium) and topography (gorges, plateaus). A list of 362 species (309 native, 53 exotic) is provided. Eight native species are of particular significance, including *Hibbertia hermanniifolia & Eucalyptus benthamii.* Floristic and structural diversity is high due to the varied geology and physiography. The increasing isolation of the vegetation of Bents Basin State Recreation Area as a result of clearing for agriculture and housing is an important factor for management.

Introduction

Bents Basin, a large pool formed on the Nepean River at the efflux of an impressive sandstone gorge, is on the western outskirts of Sydney 25 km south of Penrith (lat. 33°56′S, long. 150°37′E). Bents Basin is the focus of recreational activity for the State Recreation Area (S.R.A.) of which, with the exception of a nearby cleared 20 ha area, the remainder has natural vegetation (Figure 1). Bents Basin S.R.A. totals 391 ha in area and is managed by the National Parks and Wildlife Service of New South Wales.

Bents Basin was discovered in 1804 by the botanist George Caley, who named it ‘Dovedale’ (Currey 1966) though this name was not retained, and has been a popular place for botanists since the late nineteenth century. Collections of a number of rare plants have been made there.

The Bents Basin State Recreation Area was established in 1981, despite years of lobbying by the local and scientific community for specific dedication of the area as a Nature Reserve. The newly appointed S.R.A. Trust, faced with increasing recreational demands and potential conflicts with nature conservation, commissioned studies on archaeology, fauna and vegetation as a basis for a future Plan of Management. This paper is based on a vegetation survey (Thomas, Burkitt & Benson 1984) undertaken in 1983 to determine the distribution of plant communities within the S.R.A. and to recommend management guidelines and priorities.

Topography and geology

Bents Basin S.R.A. is on the eastern escarpment of the Blue Mountains plateau, adjacent to the western edge of the Cumberland Plain. Here the Nepean River has cut a deep gorge through the distinctive Hawkesbury Sandstone. The S.R.A. can be divided into a number of topographic regions (Figure 2) Bents Basin itself; the Nepean River and Forest Hill Creek gorges; and the Little Mountain and Forest Hill creek plateaus.

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Bents Basin is a circular pool about 120 m across, formed at the efflux of the Nepean River from the Hawkesbury Sandstone gorge. Its particular configuration may be attributed to the underlying presence of a volcanic neck (W. Holland, L. Fowler pers. comm.). To the east of the Basin is a cleared undulating (20 ha) paddock on the clay soils from the Wianamatta Shale of the Cumberland Plain now developed for visitor parking and picnicking. Two small creeks cross this area. Upstream of the Basin the narrow Nepean River gorge has separated the Hawkesbury Sandstone plateau of Little Mountain from the main plateau further west. Little Mountain is up to 160 m in elevation and has remnant caps of Wianamatta Shale. The eastern edge of Little Mountain rises steeply from the cleared Wianamatta Shale country of the Cumberland Plain along the Lapstone Monocline-Nepean Fault (Herbert & Helby 1980).

The south-western arm of the S.R.A. follows Forest Hill Creek which drains a similar plateau. Its gorge is narrower and more sheltered than the Nepean River gorge. There are two alluvial deposits where the Nepean River changes direction; at Campbells Ford at the southern end of Little Mountain and on the eastern margin of Bents Basin.

Average annual rainfall at Wallacia is 952 mm (Bureau of Meteorology 1979) with a peak in summer. Average maximum temperature for January is 29°C and average minimum temperature for July is 1–2°C.

Methods

Black and white aerial photography (N.S.W. Department of Lands 1:16 000, County of Cumberland Series 1978) was used to identify plant community boundaries. These were confirmed during extensive field, reconnaissance and a vegetation map (Figures 3a & b) prepared. In the field community recognition was based on dominant species and habitat. With limited time available and a diverse area to deal with, traditional subjective procedures were considered the most efficient. Within each recognised community, data were collected from circular samples, each with an area of 400 square metres. There were 21 sites marked permanently to enable further recording. Information collected at each quadrat included species present and their abundance, physiography (location, geology, aspect, elevation, slope and topography), a general description of the community (height and percentage cover for main species of each stratum) and a note of any disturbance. Vegetation structure was classified using height of the dominant stratum and projective foliage cover (Specht 1981). The distribution of the rare species, *Hibbertia hermanniifolia*, was examined separately and height, width and number of stems of 53 plants were measured.

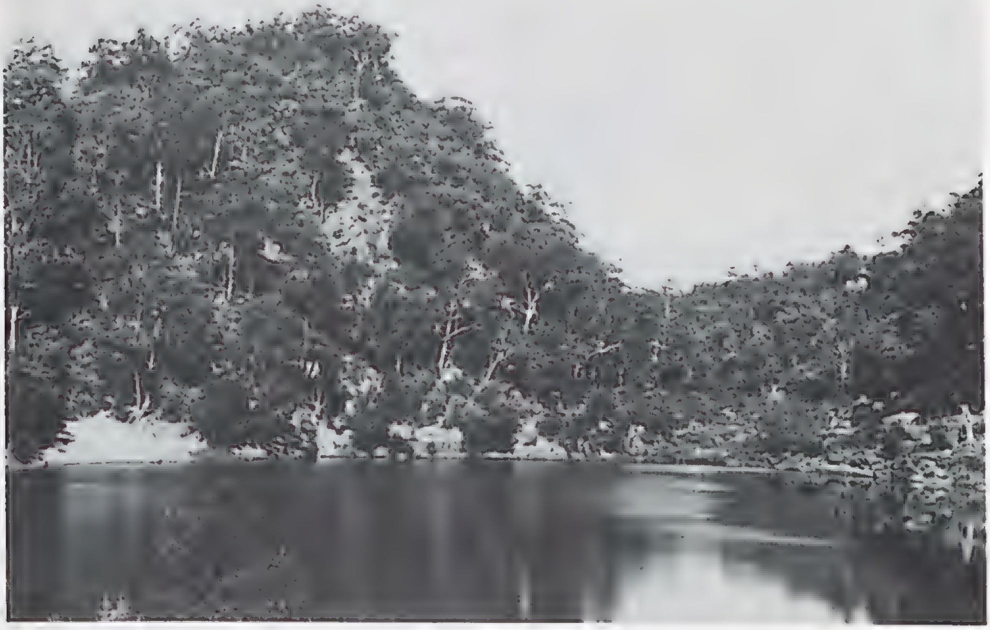


Figure 1. The Nepean River gorge with Bents Basin in the foreground and Little Mountain to the left as it appeared after drought in 1982.

Description of plant communities

1. Tall open-forest – *Eucalyptus benthamii*

On the eastern half of the sand deposit, east of the Basin is tall open-forest of *E. benthamii* with trees originally up to 40 m in height but seriously damaged by fire in 1979 (see Benson, 1985). There are also smaller trees of *E. elata.* The shrub understorey is quite dense in places and consists mostly of *Acacia binervia, Bursaria spinosa* and *Hymenanthera dentata.* Much of this layer and the ground cover is overrun by the climbing exotics **Senecio mikanioides, *Asparagus asparagoides* and **Araujia hortorum.* The sandbank is not level here and there are a number of slight hollows in which **Tradescantia albiflora* forms a dense ground-covering mat. Native climbing and trailing species include *Clematis glycinoides, C. aristata* and *Cayratia clematidea.* These are not as abundant as the exotic species. On higher ground *Pteridium esculentum, *Cynodon dactylon* and **Conyza albida* are prominent.

2. Tall open-forest – *Eucalyptus deanei*

At Campbells Ford where the Nepean River swings around the southern end of the Little Mountain plateau is a small alluvial deposit with a tall open-forest of *Eucalyptus deanei, E. elata* and *Angophora subvelutina.* Part of this has been cleared and the ground cover has *Imperata cylindrica, Pteridium esculentum*

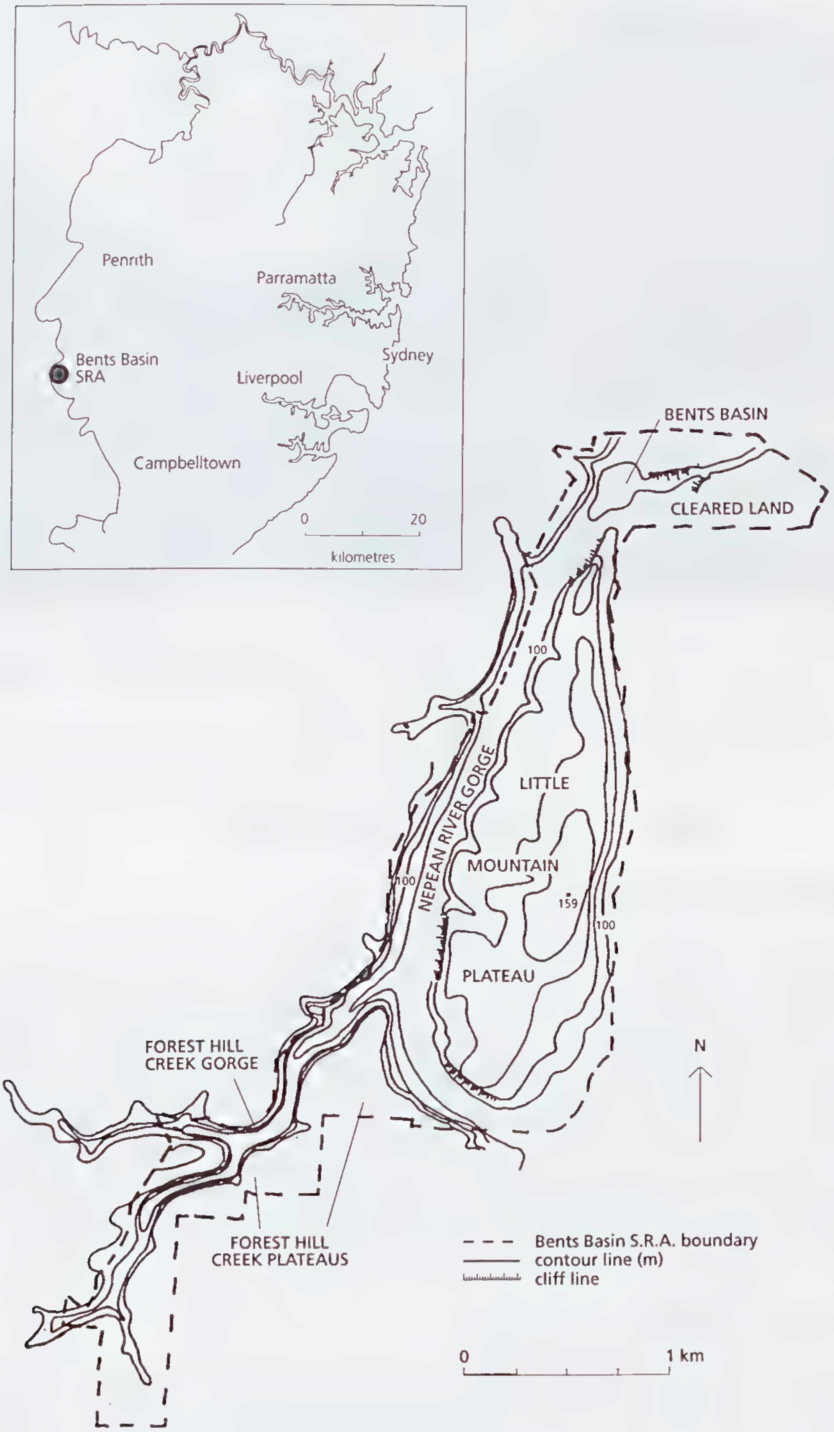


Figure 2. Map of Bents Basin S.R.A. showing major topographic regions.

and various exotic species. There are shrubs of *Clerodendrum tomentosum* and *Eucalyptus elata* saplings.

3. Tall open-forest – *Angophora subvelutina, E. deanei*

On the north-western edge of the Basin a tall open-forest of *Angophora subvelutina, Eucalyptus pilularis* and *E. deanei* is confined to a sheltered southern aspect with colluvial soils on the lower slopes of the sandstone hillside. A prominent feature of this community is the dense understorey of *Backhousia myrtifolia.*

The ground cover is quite diverse. *Hydrocotyle acutiloba* forms a thick carpet-like growth in places, while on rock outcrops *Doodia aspera* is common. Other ground species include *Pratia purpurascens. Asplenium flabellifolium, Adiantum aethiopicum, Oplismenus imbecillis* and *Microlaena stipoides.*

4. Open-forest – *Syncarpia glomulifera, Glochidion ferdinandi, Ceratopetalum apetalum, Backhousia myrtifolia*

The Forest Hill Creek gorge drops 20 to 50 metres in elevation along its length of 800 m and in combination with its narrow width (5 to 15 m) and sheltered south-easterly aspect, this results in vegetation being distinctly different from the vegetation along the Nepean River gorge (Community 20). There is a dense canopy of small trees *Glochidion ferdinandi, Backhousia myrtifolia, Notelaea longifolia, Ceratopetalum apetalum, Syncarpia glomulifera* and *Tristaniopsis laurina* with virtually no shrub layer. The most striking feature is the high number of ferns and orchids. Ferns include *Sticherus flabellatus, Todea barbata, Davallia pyxidata, Adiantum aethiopicum, A. hispidulum* and *Asplenium flabellifolium, Cyathea australis* and *Culcita dubia* occur but are less common. Orchids recorded in the gorge were *Dendrobium speciosum, D. linguiforme, Liparis reflexa* and *Bulbophyllum exiguum.* One plant of *Dendrobium pugioniforme* was found. The sedge *Schoenus melanostachys* was common on the rock walls. Vines were also common and included *Smilax glyciphylla* and *Eustrephus latifolius.*

5. Open-forest – *Eucalyptus crebra*

At the southern end of Little Mountain plateau on a remnant of Wianamatta Shale is open-forest of the ironbarks *Eucalyptus crebra* and *E. fibrosa* with *E. punctata, E. eugenioides,* with *Allocasuarina torulosa* and *Persoonia linearis.* The grassy ground cover of *Themeda australis, Panicum* sp. and various herbs shows the shale influence.

6. Open-forest – *Allocasuarina torulosa, Eucalyptus pilularis, E. eximia, E. punctata, E. eugenioides*

Open-forest found on the middle of the Little Mountain plateau also shows a shale influence. Conspicuous is *Allocasuarina torulosa*, which occurs as a thick sub-canopy layer under the taller trees, *Eucalyptus eximia, E. pilularis, E. punctata & E. eugenioides.* Shrub species include *Persoonia linearis* and *Leucopogon muticus.* Ground cover consists of *Xanthorrhoea minor, Panicum simile, Entolasia stricta, Pomax umbellata* and a variety of other grasses and herbs.

	COMMUNITY STRUCTURE	MAIN SPECIES
1	TALL OPEN-FOREST	*Eucalyptus benthamii, Eucalyptus elata*
2		*Eucalyptus deanei, Angophora subvelutina, Eucalyptus elata*
3		*Eucalyptus deanei, Angophora subvelutina*
4	FOREST	*Syncarpia glomulifera, Glochidion ferdinandi* *Ceratopetalum apetalum, Backhousia myrtifolia*
5	OPEN-FOREST	*Eucalyptus crebra*
6		*Allocasuarina torulosa, Eucalyptus pilularis, Eucalyptus eximia, Eucalyptus punctata, Eucalyptus eugenioides*
7		*Eucalyptus tereticornis*
8	TALL WOODLAND / OPEN-FOREST	*Eucalyptus pilularis, Syncarpia glomulifera, Angophora costata*
9	WOODLAND	*Eucalyptus gummifera*
10		*Eucalyptus gummifera, Angophora costata, Eucalyptus pilularis, Allocasuarina torulosa*
11		*Eucalyptus eximia*
12		*Eucalyptus eximia, Angophora costata, Eucalyptus pilularis, Eucalyptus punctata*
13		*Eucalyptus punctata, Eucalyptus eugenioides, Eucalyptus pilularis, Allocasuarina littoralis*
14		*Eucalyptus punctata, Eucalyptus eugenioides*
15		*Eucalyptus maculata, Eucalyptus fibrosa*
16		*Eucalyptus maculata, Eucalyptus punctata, Eucalyptus eugenioides, Angophora costata*
17		*Eucalyptus sparsifolia (oblonga), Eucalyptus gummifera, Angophora costata*
18		*Eucalyptus notabilis, Eucalyptus eugenioides, Eucalyptus gummifera, Eucalyptus pilularis*
19		*Melaleuca styphelioides*
20		*Tristaniopsis laurina, Casuarina cunninghamiana*
21	SCRUB	*Leptospermum flavescens, Kunzea ambigua*
22	SEDGE / SHRUBLAND	*Banksia spinulosa, Hakea dactyloides, Lepyrodia muelleri, Anisopogon avenaceus*
23	GRASSLAND	*Cynodon dactylon*
24		**Paspalum dilatatum, Themeda australis, *Lolium rigidum*
25	REGENERATING	Various, according to location

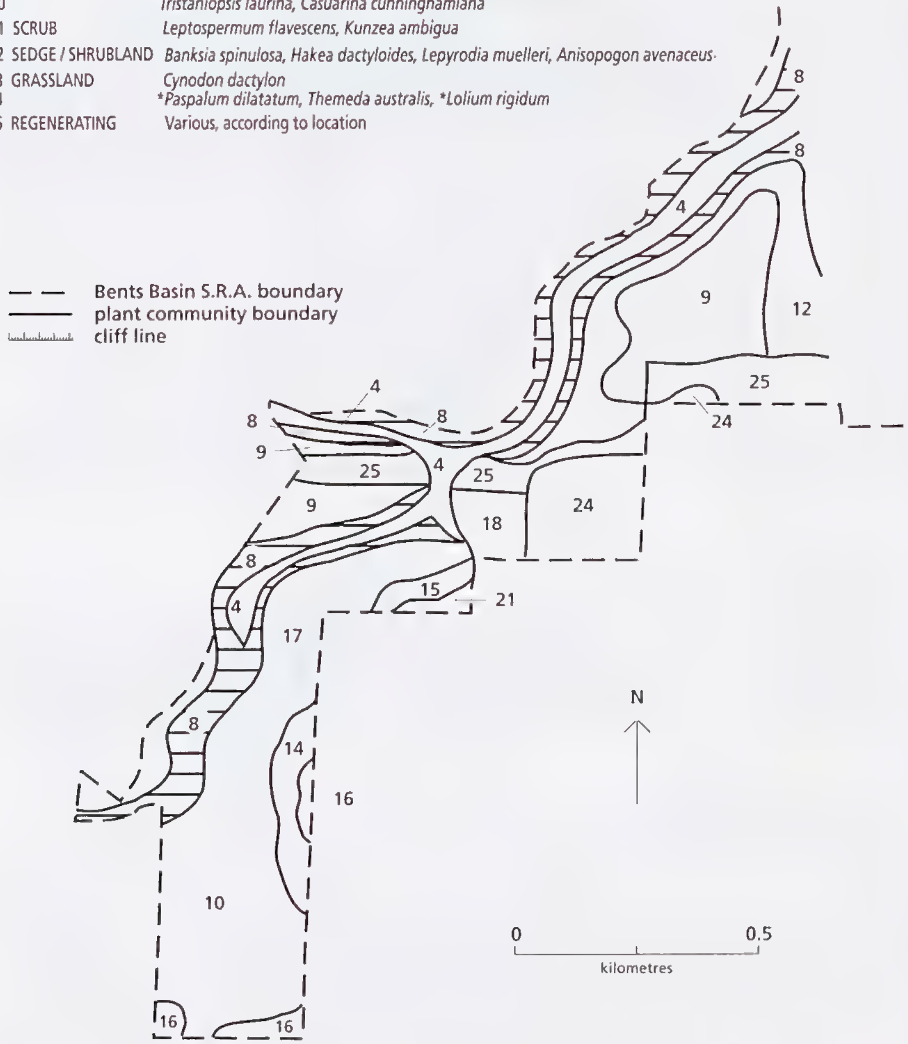
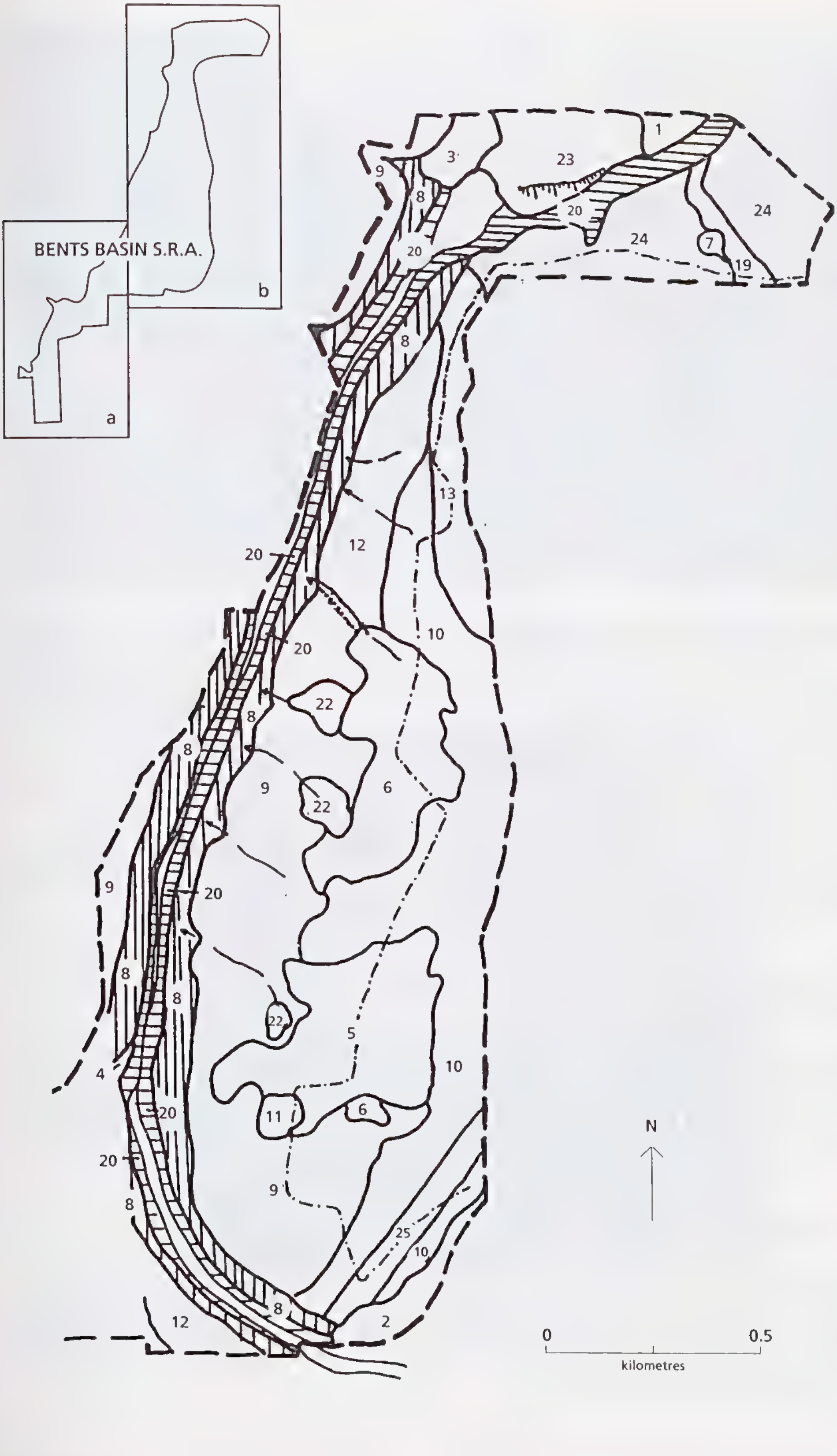


Figure 3. The plant communities of Bents Basin S.R.A. showing (a) Forest Hill Creek section and (b) Little Mountain section.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7. Open-forest – *Eucalyptus tereticornis*

A small stand of young *Eucalyptus tereticornis* grows close to the creek near the north-eastern (Wolstenholme Drive) entrance to the S.R.A. The stand is characterised by a few older trees and a mixture of young trees and seedlings. There are only a few shrubs including *Bursaria spinosa* and **Olea europaea* subsp. *africana*. The ground cover is sparse and is similar in species composition to the *Melaleuca styphelioides* woodland (Community 19).

8. Tall woodland/Open-forest – *Eucalyptus pilularis, Syncarpia glomulifera*

The rocky upper slopes of the gorge of the Nepean River and Forest Hill Creek support open-forest dominated by *E. pilularis*. Towards the top of these slopes is woodland vegetation with scattered trees of *E. eximia* while further down the slope *E. pilularis* and *Angophora costata* are more common. *Syncarpia glomulifera* is more common closer to the river. There also appear to be a few trees of *Eucalyptus agglomerata* opposite the junction of Forest Hill Creek. The large open areas of rock and the thin skeletal soil result in a sparse shrub understorey consisting mainly of *Bossiaea rhombifolia, Persoonia linearis* and *Leptospermum attenuatum*. Ground plants include *Lomandra confertifolia* subsp. *rubiginosa, Pomax umbellata* and *Phyllanthus thymoides* (Figure 4).

9. Woodland – *Eucalyptus gummifera*

On the south-western side of the Little Mountain plateau is woodland of *Eucalyptus gummifera* and *E. punctata* with some *E. eugenioides* and *Angophora costata*. The understorey is dense, with *Lambertia formosa, Petrophile pedunculata, Leptospermum attenuatum* and *Leucopogon muticus*. *Caustis flexuosa* is the most prominent ground species amongst various herbs and grasses.

Similar vegetation occurs on the Forest Hill Creek plateau above the junction of Forest Hill Creek and Nepean River and above the junction of the two arms of Forest Hill Creek.

10. Woodland – *Eucalyptus gummifera, Angophora costata, E. pilularis, Allocasuarina torulosa*

This occurs on the south-eastern side of Little Mountain and the upper part of Forest Hill Creek. The understorey is not as dense as the western side, and consists of shrubs of *Persoonia linearis, Leucopogon muticus* and patches of *Acacia falciformis*. The ground cover is thick, with *Pteridium esculentum, Stypandra glauca* and *Xanthorrhoea minor*.

11. Woodland – *Eucalyptus eximia*

On top of Little Mountain near the shale/sandstone junction is a small area of *E. eximia* woodland. The shrub understorey is sparse with *Leucopogon muticus* and *Persoonia linearis*. The ground cover is characterised by grasses such as *Themeda australis* and *Anisopogon avenaceus*. Localised soil conditions appear to be related to its occurrence.

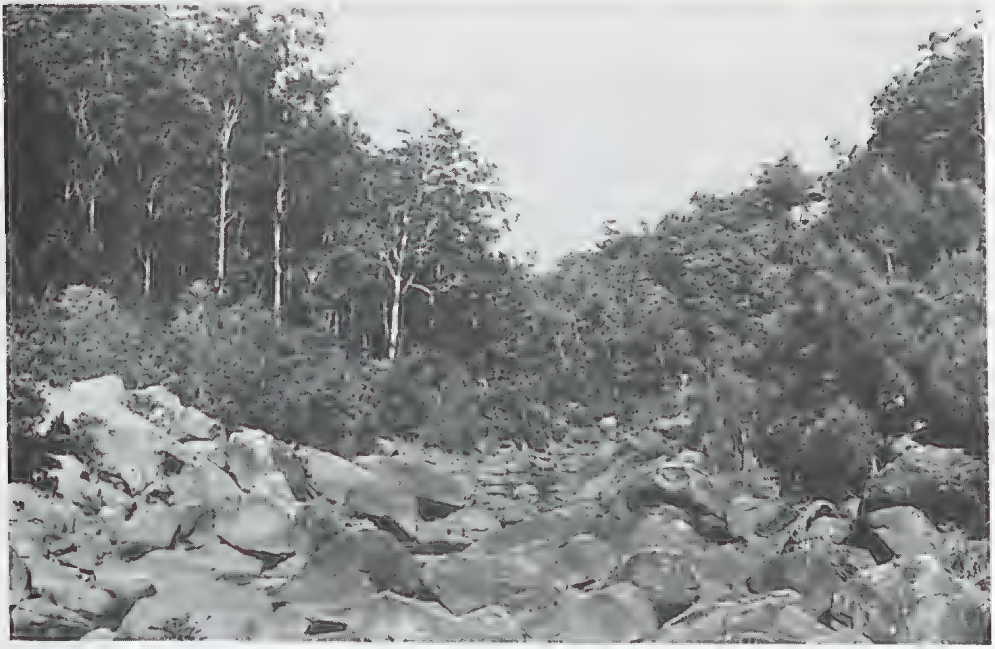

Figure 4. The rocky bed of the Nepean River with woodland of *Tristaniopsis laurina* and *Casuarina cunninghamiana* (Community 20) and further up the slopes Tall Woodland/Open-forest supporting *Eucalyptus pilularis* and *Syncarpia glomulifera* (Community 8).

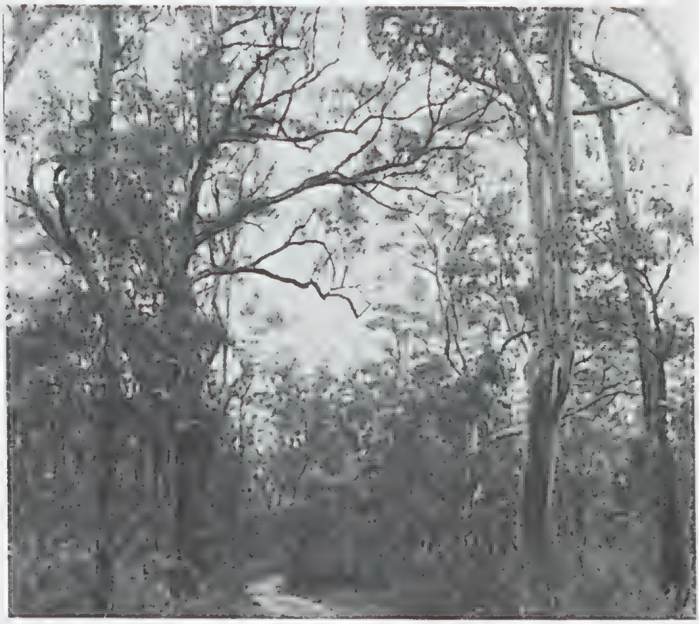

Figure 5. Woodland of *Eucalyptus eximia, Angophora costata, E. pilularis* and *E. punctata* (Community 12) growing on the north-western end of the Little Mountain plateau.

12. Woodland – *Eucalyptus eximia, Angophora costata, E. pilularis, E. punctata*

The vegetation on the north-western end of the Little Mountain plateau differs from that further south. The plateau becomes narrower and slopes gently to the west. In these areas *Eucalyptus eximia* becomes more prominent than *E. gummifera.* Other trees such as *Angophora costata, E. pilularis* and *E. punctata* are common. In small gullies running in a north-westerly and westerly direction, the vegetation is more sheltered and *Syncarpia glomulifera* is prominent with shrubs of *Astrotricha latifolia* and *Banksia spinulosa* (Figure 5).

Similar woodland occurs on the upper slopes and exposed rocky parts of Forest Hill Creek, especially on the southern side. In places *E. eximia* occurs alone but over most of the area it is associated with *A. costata, E. pilularis, E. eugenioides* and the occasional *E. punctata* and *Syncarpia glomulifera.* The shrub layer is floristically similar to the *E. gummifera* woodland but it is much less dense.

13. Woodland – *Eucalyptus punctata, E. eugenioides, E. pilularis, Allocasuarina littoralis*

On the north-eastern slope of Little Mountain is woodland of *E. punctata* with some *E. eugenioides* and *E. pilularis. Allocasuarina littoralis* and *Exocarpos cupressiformis* are common tall shrub species. *Imperata cylindrica* is a common ground cover species, together with various herbs, *Wahlenbergia gracilis, Kennedia rubicunda, *Conyza albida* and *Solanum prinophyllum.*

14. Woodland – *Eucalyptus punctata, E. eugenioides*

On the flat areas near the south-eastern border of the Forest Hill Creek section of the S.R.A. a small area of woodland with *E. punctata* and *E. eugenioides* occurs. The shrub layer is sparse and similar to the woodland described above. The ground cover is predominantly *Themeda australis* and *Lepidosperma laterale.* This vegetation is distinctly influenced by the shale soils that occur more extensively on the adjacent cleared lands.

15. Woodland – *Eucalyptus maculata, E. fibrosa*

A very small area of woodland with *Eucalyptus maculata* and *Eucalyptus fibrosa* occurs on the edge of the S.R.A. in the Forest Hill Creek section. This woodland is a remnant of the vegetation of the nearby Wianamatta Shale that has been extensively cleared for agriculture. The shrub layer is sparse and consists mainly of *Leucopogon muticus, Daviesia ulicifolia* and *Lissanthe strigosa.* The ground cover is characterised by *Cheilanthes sieberi, Danthonia* sp., *Echinopogon caespitosus* and *Lomandra longifolia.*

16. Woodland – *Eucalyptus maculata, E. punctata, E. eugenioides, Angophora costata*

On the flat areas along the southern boundary of the Forest Hill Creek section of the S.R.A. woodland of *Eucalyptus maculata* with *E. punctata, E. eugenioides, Angophora costata* and *Syncarpia glomulifera* occurs. The understorey is similar to Community 15. This woodland occurs as small disjunct areas.

17. Woodland – *Eucalyptus sparsifolia (oblonga), E. gummifera, Angophora costata*

This community is found on the eastern slope above the south arm of Forest Hill Creek. It is associated with sandstone occurring closer to the gully and contrasts with the *E. punctata, E. eugenioides* woodland (Community 14) found nearby on the shale/sandstone boundary. The shrub layer is dominated by *Leptospermum attenuatum* with occasional thickets of *Hakea sericea* and *Banksia spinulosa.* The ground cover is characterised by *Xanthorrhoea minor* and a variety of herbs and grasses.

18. Woodland – *Eucalyptus notabilis, E. gummifera, E. pilularis, E. eugenioides*

A woodland community with *E. notabilis, E. gummifera, E. pilularis* and *E. eugenioides* is associated with the shale derived-soils on the plateau areas above Forest Hill Creek. The shrub layer is diverse with the dominant species being *Leptospermum attenuatum, Leucopogon muticus,* and *Persoonia linearis.* The ground cover is characterised by *Xanthorrhoea minor* and *Lomandra obliqua.*

19. Woodland – *Melaleuca styphelioides*

Two creeks cross the paddocks south-east of the Basin and are lined with large *Melaleuca styphelioides, *Gleditsea triacanthos* and **Celtis occidentalis.* On the sides of the creek the native shrub understorey has largely been replaced by exotic species such as **Ligustrum sinense, *Tradescantia albiflora, *Araujia hortorum, *Robus* sp. and **Olea europaea* subsp. *africana.* The ground cover species consist mostly of **Paspalum dilatatum* and **Verbena bonariensis* which have taken over from *Themeda australis.* Other exotics growing in this community are **Sida rhombifolia, *Gnaphalium sphaericum, *Taraxacum officinale, *Bidens pilosa, *Phalaris minor, *Gomphocarpus fruticosus* and **Xanthium chinense.*

20. Woodland – *Tristaniopsis laurina* and *Casuarina cunninghamiana*

This community occurs on alluvium along the Nepean River up to 10 metres either side of the river. Tree species are *Tristaniopsis laurina* and *Casuarina cunninghamiana.* The ground is sparsely covered with *Setaria geniculata* var. *pauciseta* and *Persicaria hydropiper* and the exotic species **Anonopus affinus.* Other exotic species including **Ligustrum sinense* and **Gleditsea triacanthos* occur predominantly along the river bank. On an accumulation of silt at the intersection of Bushrangers Creek and the Nepean River the exotic **Ligustrum sinense* is crowding out the native shrub/tree layer of *Glochidion ferdinandi, Callicoma serratifolia, Ceratopetalum apetalum* and *Backhousia myrtfolia.*

21. Scrub

Scrub is confined to a small poorly-drained site along the eastern boundary of the S.R.A. on the Forest Hill plateau. It is dominated by *Leptospermum flavescens* and *Kunzea ambigua.*

22. Sedge/Shrubland

At the top of several gullies running in a westerly direction from the Little Mountain plateau are poorly drained sites with sedge/shrubland. These are dominated by sedges and grasses particularly *Anisopogon avenaceus, Entolasia marginata* and *Lepyrodia muelleri* and the shrubs *Banksia spinulosa* and *Hakea dactyloides.* There is a sparse tree canopy of *Eucalyptus eximia.* As the topography gets steeper and rockier towards the river, the usual woodland eucalypts as well as *Syncarpia glomulifera,* and the shrub *Astrotricha latifolia* become prominent, along the edges of intermittent watercourses.

23. Grassland – **Cynodon dactylon*

The vegetation present on the western half of the sand deposit near the Basin is characterised by the grass *Cynodon dactylon* which forms a thick ground cover stabilising the sand. Clusters of small trees of *Acacia binervia* occur with occasional *A. parramattensis* and *Backhousia myrtifolia.* At the edge of the Basin, *A. binervia, *Gleditsea triacanthos, Casuarina cunninghamiana* and *Eucalyptus elata* are common. Prominent exotic species in the grassland are **Hypochoeris radicata, *Taraxacum officinale, *Conyza albida, *Bidens pilosa* and *Setaria geniculata* var. *pauciseta.* Small patches of *Pteridium esculentum* and *Lomandra longifolia* are found on the sand deposit. Where the river leaves the Basin and flows along the southern side of the sand deposit the vegetation changes to *Casuarina cunninghamiana* and young *Eucalyptus elata, *Gleditsea triacanthos, Acacia floribunda* and *Acacia parramattensis* grow along the river bed while on the northern side of the sand-deposit, in the flood channels, there is a tall thicket of *Acacia floribunda.*

24. Grassland – **Paspalum dilatatum*

This occurs on the cleared paddocks south-east of the Basin and on the plateau south of the junction of Forest Hill Creek and the Nepean River. The main grasses present are **Paspalum dilatum, *Lolium rigidum* and *Themeda australis.* They have been cleared and grazed for many years.

25. Regeneration Areas

Two sites are regenerating following disturbance. Under electricity transmission lines that cross the south-west corner of the Little Mountain plateau and Forest Hill Creek, native shrubs are regenerating after lopping. Complete recovery will not occur as they are regularly lopped. The second area is a small corridor in the Forest Hill Creek section of the S.R.A. that has been partially cleared. This area is successfully regenerating and contains many of the native species from the adjacent woodland communities including *Eucalyptus gummifera, E. eximia, Leucopogon muticus* and *Leptospermum attenuatum.* Ground cover species include *Themeda australia, Aristida vagans, Phyllanthus thymoides* and *Pomax umbellata.* Exotics are common but not abundant and included **Taraxacum officinale* and **Senecio madagascariensis.*

Discussion

Plant communities

Over 20 naturally-occurring plant communities have been identified in Bents Basin S.R.A. These range in structure from tall open-forest on the alluvial soils, to scrub and sedge/shrubland on the higher parts of the plateaus. This variation relates firstly to the range of habitats available in a small area – there are, for example, the sheltered gorges of Forest Hill Creek, the dry exposed edges of the sandstone plateaus and the flood-prone, boulder-strewn reaches of the Nepean gorge, and secondly to the range of soil types present each of which has a strong influence on the vegetation pattern (Figure 6). The Hawkesbury Sandstone soils predominate, poor sandy soils on the edges of the plateaus, but deeper and richer on the lower hillslopes as a result of downslope movement. The more fertile clay soils of the Wianamatta Shale provide different conditions. On the Little Mountain plateau these occur as thin isolated remnants, with eroding clay material often influencing the vegetation composition on adjacent sandstone soils. The clay/sandstone interface also influences drainage conditions. In the upper part of Forest Hill Creek catchment, Wianamatta Shale formed a deeper, more extensive cover over the sandstone. This has mostly been cleared for agriculture but remnants of the plant communities are within the S.R.A., though of very limited extent. As well as soils derived from sandstone and shale there are small patches of alluvial soils at Bents Basin and Campbells Ford.

Table 1. Species of particular significance in Bents Basin S.R.A. with notes on habitat/location, significance and potential threat. (Significance Codings from Briggs & Leigh (1988)).

Species	Habitat/Location	Significance	Potential threats
Hibbertia hermanniifolia (Dilleniaceae)	In scattered groups on flat benches of skeletal sandy soil between rocky cliff faces, on the north-west facing ledges of Nepean River gorge at northern end of Little Mtn.	Coded 3RCa: known only from Bents Basin S.R.A., Wadbilliga National Park and East Gippsland Vic.	Heavy recreation pressures, changes in fire patterns, invasion of exotic plant species.
Eucalyptus benthamii (Myrtaceae)	One small population on Nepean River bank in north-eastern corner of S.R.A.	Coded 2VCi: originally occurred on flats of Nepean River and tributaries. Most of original habitat has been cleared or submerged by Lake Burragorang. Population on Kedumba Creek but only scattered individuals along Nepean River now.	Changes in flood and fire patterns, and mismanagement may destroy population at Bents Basin. Increase in height of Warragamba Dam storage will destroy population at Kedumba Creek.
Gonocarpus longifolius (Haloragaceae)	Found on cliffs above southern rim of the Basin growing near the *H. hermanniifolia* population. Only two plants have been recorded.	Coded 3RC-	Increased visitor usage, changes in fire patterns.

Species	Habitat/Location	Significance	Potential threats
Lomandra fluviatilis (Lomandraceae)	Found in sandstone crevices on the lower slopes of the Nepean gorge below flood level.	Coded 3RC-: found sporadically along creeks in sheltered sandstone gullies around Sydney, where alluvial sediment has accumulated between rock debris.	Invasion by exotic plant species, deterioration of river water quality.
Lissanthe sapida (Epacridaceae)	Found in Hawkesbury Sandstone woodland vegetation on Little Mtn and Forest Hill Creek plateaus.	Coded 3RCa: on sandstone plateaus and along river banks in Blue Mtns and Woronora Plateau areas.	Clearing of vegetation, changes in fire patterns, invasion by exotic plant species.
Eucalyptus tereticornis (Myrtaceae)	Small population near the Wolstenholme Drive entrance.	Locally interesting species once common on shale derived soils of the Cumberland Plain, extensively cleared.	Clearing of vegetation.
Acacia falciformis (Fabaceae)	Found on eastern side of Little Mountain growing in groups of 20 plants. Also occurs ocasionally elsewhere on Little Mtn, on northern edge of the Basin and around southern rim of Forest Hill Creek.	Locally interesting species commonly found on the Tablelands, has only been recorded in the Sydney area at Bents Basin and at Menangle.	Clearing of vegetation, changes in fire patterns.
Acacia uncinata subsp. *uncinata* (Fabaceae)	Found on top of Nepean gorge, on the western side near electricity transmission lines.	Locally interesting species, only previous recordings of this taxon in the Central Coast botanical subdivision are from Glen Davis and just south of Putty, both locations over 80km from Bents Basin S.R.A.	Clearing of vegetation, changes in fire patterns.

Bents Basin S.R.A. is a small area of natural vegetation, becoming increasingly isolated (see below), and it is important to recognise as much potential variation as possible, as the successful long-term management of plant and animal diversity depends on the maintenance of this variation. As a result the degree of difference between plant communities varies. Some are clearly distinctive while others differ only in a number of plant species. It is important to realise that the recognition of variation depends on the scale. For example in terms of the mapping units of the Sydney Region 1:100 000 Vegetation Mapping Series (e.g. Keith & Benson 1988), the 25 communities would be allocated to about 8 map units. In fact, of the plant communities recognised here, 14 would be included within the Hawkesbury Sandstone Complex of Keith & Benson.

Prior to European settlement, woodland and forest extended across the Wianamatta Shale hills and alluvial floodplains of the Cumberland Plain. Few remnants of these communities have survived the extensive clearing for agriculture and housing that has since taken place. The small occurrences of these communities in Bents Basin S.R.A., the open-forests with *Eucalyptus crebra* (Community 5) and of *E. tereticornis* (Community 7) and the woodlands with *E. maculata* (Communities 15, 16) and *Melaleuca styphelioides* (Community 19) the tall open-forests of *E. deanei* and *E. benthamii* (Communities 1, 2) are therefore of regional conservation significance. Being adjacent to sandstone areas in the S.R.A., many of the plant communities recognised show intergrading features in their floristic composition and provides the opportunity for studies of species interactions on these very different soil types. The Forest Hill Creek gorge vegetation with its many ferns and orchids is significant because of its relatively undisturbed nature.

Species richness

Species richness (the number of different species found in a given area) in Bents Basin S.R.A. is high for its small area (391 ha). The 309 native plant species recorded (Table 2, Appendix I), compares with the 320 species recorded in Bouddi National Park's 1160 ha (McRae & Benson 1983) and the 620 recorded species within the 11000 ha of Brisbane Water National Park (Benson & Fallding 1981). Both these National Parks are predominantly sandstone environments.

Like the plant community variation, the high species richness in the S.R.A. appears to be related to its particular combination of geography, geology and physiography. The varied landforms, including two plateaus with associated slopes, two major gorges and a number of minor valleys, undulating pastoral land, and alluvial deposits provide a variety of habitats, differing in soil, aspect, slope and moisture with communities that differ in structure and flora. The geology leads to further variations in the flora. Although the majority of the species were those commonly found in sandstone soils, species such as *E. punctata, Syncarpia glomulifera, Acacia falciformis, A. filicifolia, A. mearnsii, Oxylobium ilicifolium* and a large variety of grasses reflect the shale influence on the soil.

Table 2. Total native and exotic species in Bents Basin S.R.A. in comparison with Bouddi and Brisbane Water National Parks.

	Bents Basin S.R.S.	Bouddi National Park	Brisbane Water National Park
Area (ha)	391	1160	11,000
Native species	309	320	620
Exotic species	53	38	37#

# — not exhaustive

One woodland community is particularly rich in species. Community 12 with *Eucalyptus eximia, Angophora costata, E. pilularis* and *E. punctata* contains 82 plant species but covers only 6.1% of the S.R.A. area (Table 3). This community is found on soils containing both Hawkesbury Sandstone and

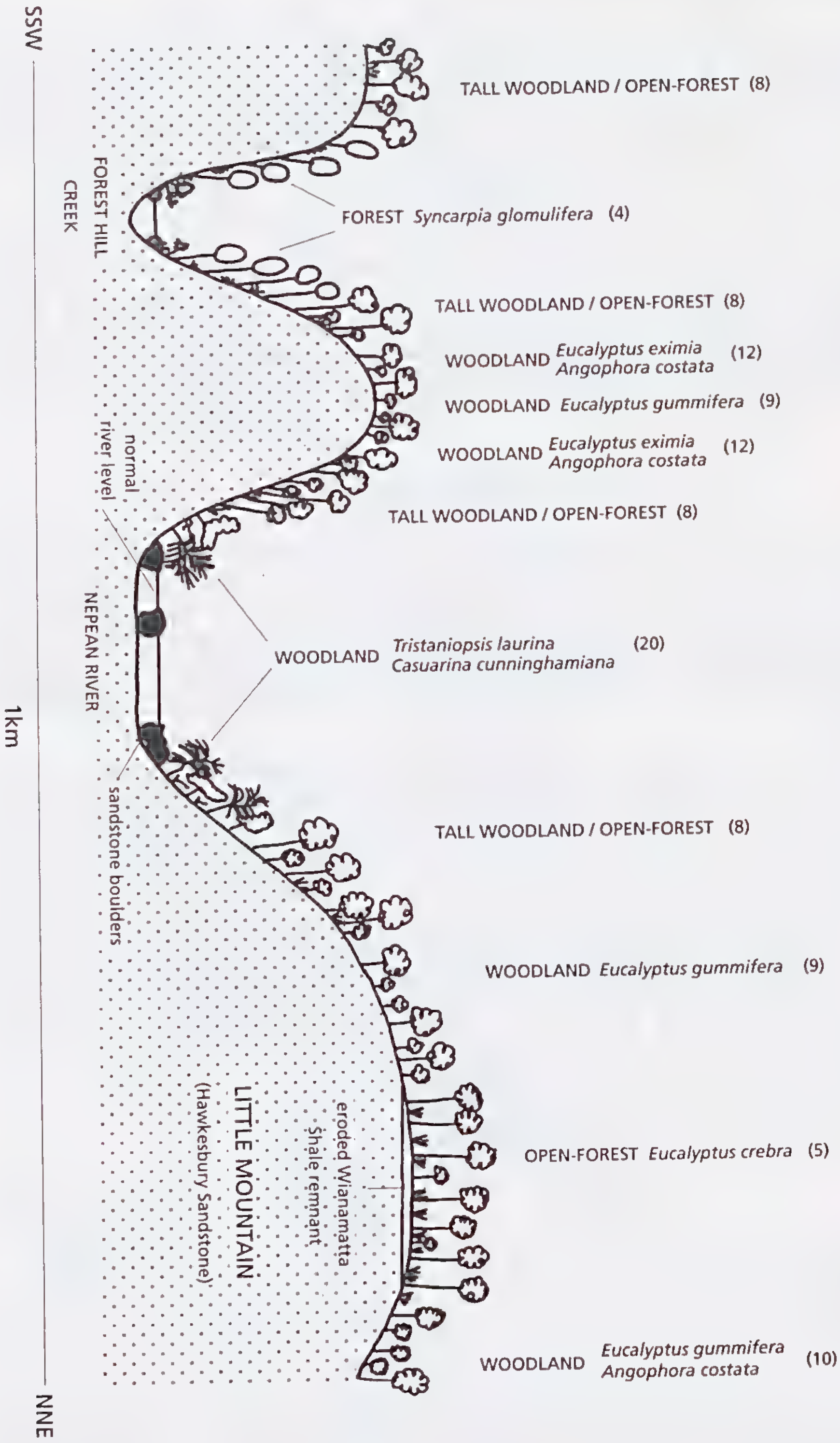
SSW
TALL WOODLAND / OPEN-FOREST (8)
FOREST HILL CREEK
FOREST *Syncarpia glomulifera* (4)
TALL WOODLAND / OPEN-FOREST (8)
WOODLAND *Eucalyptus eximia* *Angophora costata* (12)
WOODLAND *Eucalyptus gummifera* (9)
WOODLAND *Eucalyptus eximia* *Angophora costata* (12)
normal river level
TALL WOODLAND / OPEN-FOREST (8)
NEPEAN RIVER
WOODLAND *Tristaniopsis laurina* *Casuarina cunninghamiana* (20)
1km
sandstone boulders
TALL WOODLAND / OPEN-FOREST (8)
WOODLAND *Eucalyptus gummifera* (9)
LITTLE MOUNTAIN
(Hawkesbury Sandstone)
eroded Wianamatta Shale remnant
OPEN-FOREST *Eucalyptus crebra* (5)
WOODLAND *Eucalyptus gummifera* *Angophora costata* (10)
NNE

Figure 6. Schematic vegetation profile across Bents Basin S.R.A. showing relationships between plant communities, geology and topography.

Wianamatta Shale elements and this probably contributes to the variety in floristic composition of these communities.

Although the vegetation is typical of the Central Coast Botanical Subdivision, a few Central Tablelands elements (for example, *Acacia falciformis* and *Acacia uncinata* subsp. *uncinata*), contribute to the high species richness, although maximum elevation is only 160 m.

Significant species

Species of particular significance in terms of rarity or regional distribution are detailed in Table 1. The now rare Camden White Gum, *Eucalyptus benthamii* (Figure 7) (discussed by Benson 1985) occurred on the floodplain of the Nepean River system prior to European agriculture but populations are now restricted to Bents Basin and Kedumba Creek, in the Warragamba Catchment Area (Keith & Benson 1988).

The population of the shrub *Hibbertia hermanniifolia* is one of only a few occurrences of this species (the next nearest population is 300 km south in Wadbilliga National Park on the South Coast). The populations at Bents Basin S.R.A. covers 6000 square metres, with a size estimated at 500 individuals in 1984 (Thomas, Burkitt & Benson 1984). The majority of the population are between 100–150 cm high, with a few plants up to 200 cm a number of younger plants (< 50 cm), suggests recruitment in absence of fire (Figure 9). It is not known whether adult plants are killed or resprout after fire as this site has remained unburnt for at least 25 years (Figures 8, 9).

Isolated populations may indicate species that were more widespread, thousands of years ago, but as climatic conditions have changed, have become very restricted. Protecting isolated populations of species is important as further study may reveal trends in evolutionary and genetic systems.

Other species with disjunct occurrences include *Acacia falciformis* and *A. uncinata* (Table 1).

Effects of increasing isolation

Aerial photography taken since 1947 shows that Bents Basin S.R.A. is well on the way to becoming an island in an agricultural and urban landscape and that this has largely taken place in the last 25 years (Figure 10). By 1960, the woodlands of the Cumberland Plain to the east had already been cleared for more than 100 years. However, there had been much less clearing on the western side mainly because of the poorer agricultural quality of the country and Bents Basin S.R.A. remained connected with the extensive natural vegetation that still occupies the Water Board's Warragamba Catchment. This provided a reservoir and corridor for the migration of native flora and fauna. In the last 40 years, and particularly in the last 20 years increased clearing to the west has cut or reduced most of these links.

The resulting isolation is likely to have marked detrimental effects on the S.R.A.'s future species richness, both of plants and animals. The present native flora of 309 species (plus say 30 or so overlooked species) is a maximum for the area. Many species have only small populations, (e.g. *Gonocarpus longifolius*) and these species, particularly those whose original habitat has been reduced to

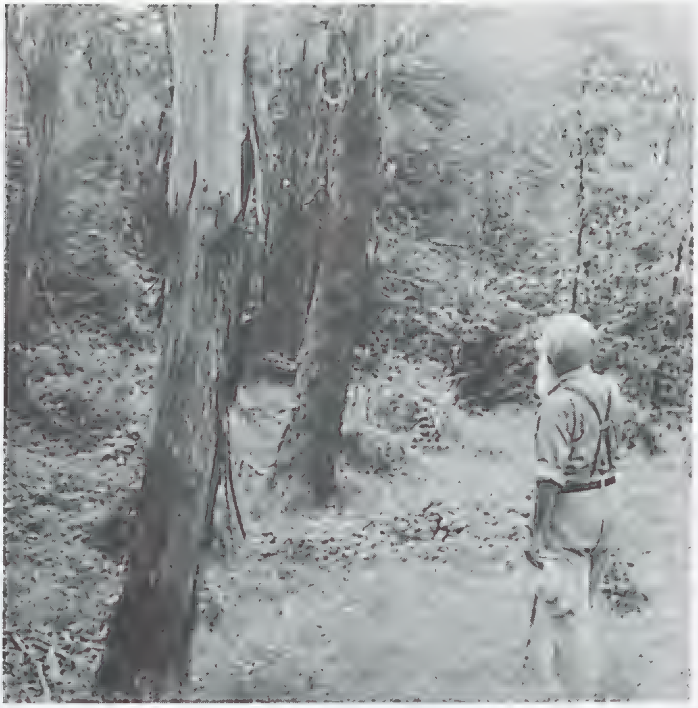

Figure 7. Young trees of *Eucalyptus benthamii* – a rare tree – growing on the sand deposit, east of the Basin (Community 1).

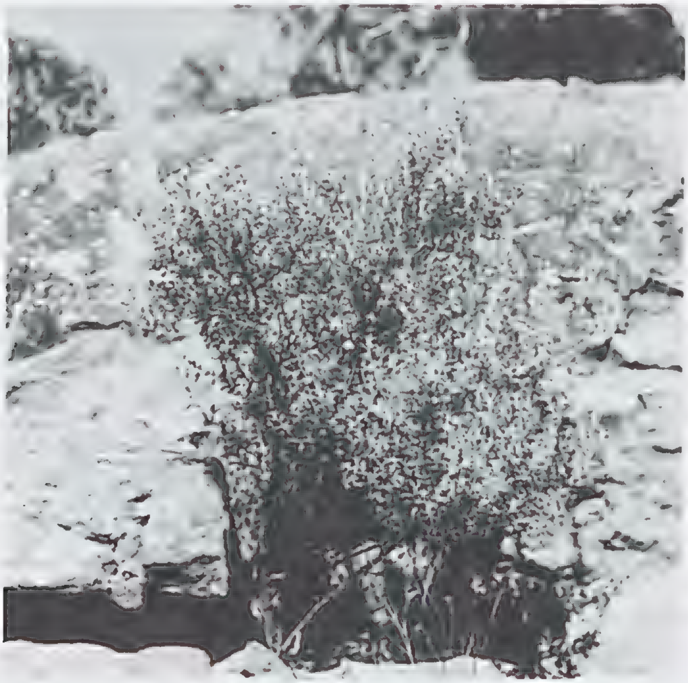

Figure 8. The rare shrub *Hibbertia hermanniifolia* found in the Tall Woodland/Open-forest of *Eucalyptus pilularis* and *Syncarpia glomulifera* on rocky ledges on north-west facing slopes of the Nepean River gorge.

marginal size, will be most vulnerable to local extinction. This may occur as a result of a reduced area of habitat available to the species as populations readjust to the changing environmental pressures resulting from isolation. These pressures include altered fire frequencies, boundary effects, nutrient increases and watercourse siltation. Added to these are the possible climatic changes related to the Greenhouse effect. The minimum population sizes needed for long-term survival is something about which little is known. Species with small populations may also be lost through accident or mismanagement. For example, the construction of a new track or picnic area may inadvertently destroy localised herb and grass species. Isolation also means that fewer areas of surrounding native vegetation are available as sources for recolonization propagules. Corridors linking nature reserves to similar areas of native vegetation increase immigration rates and maximise the chances of locally extinct species being replaced (Gorman 1979). However, it is not clear to what extent many native, particularly sclerophyllous species are readily dispersed over long distances. The destruction of corridors will decrease fauna migration (Craven 1983), and accordingly the introduction of plant propagules in animal fur or faeces will be reduced.

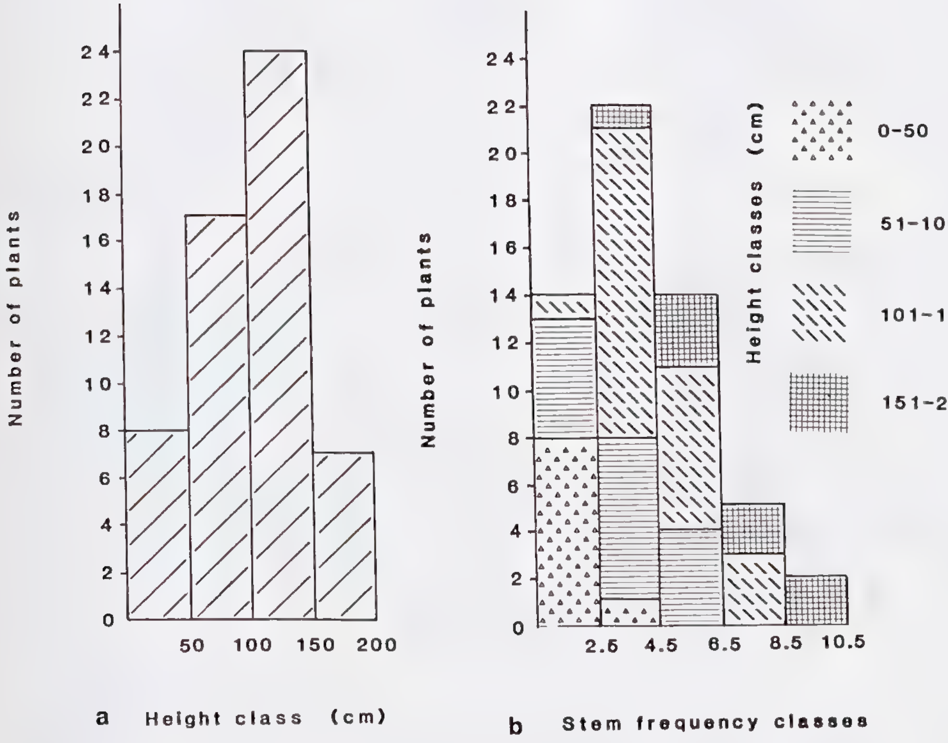

Figure 9. *Hibbertia hermanniifolia* **a** height class frequency and **b** stem frequency with height classes indicated.

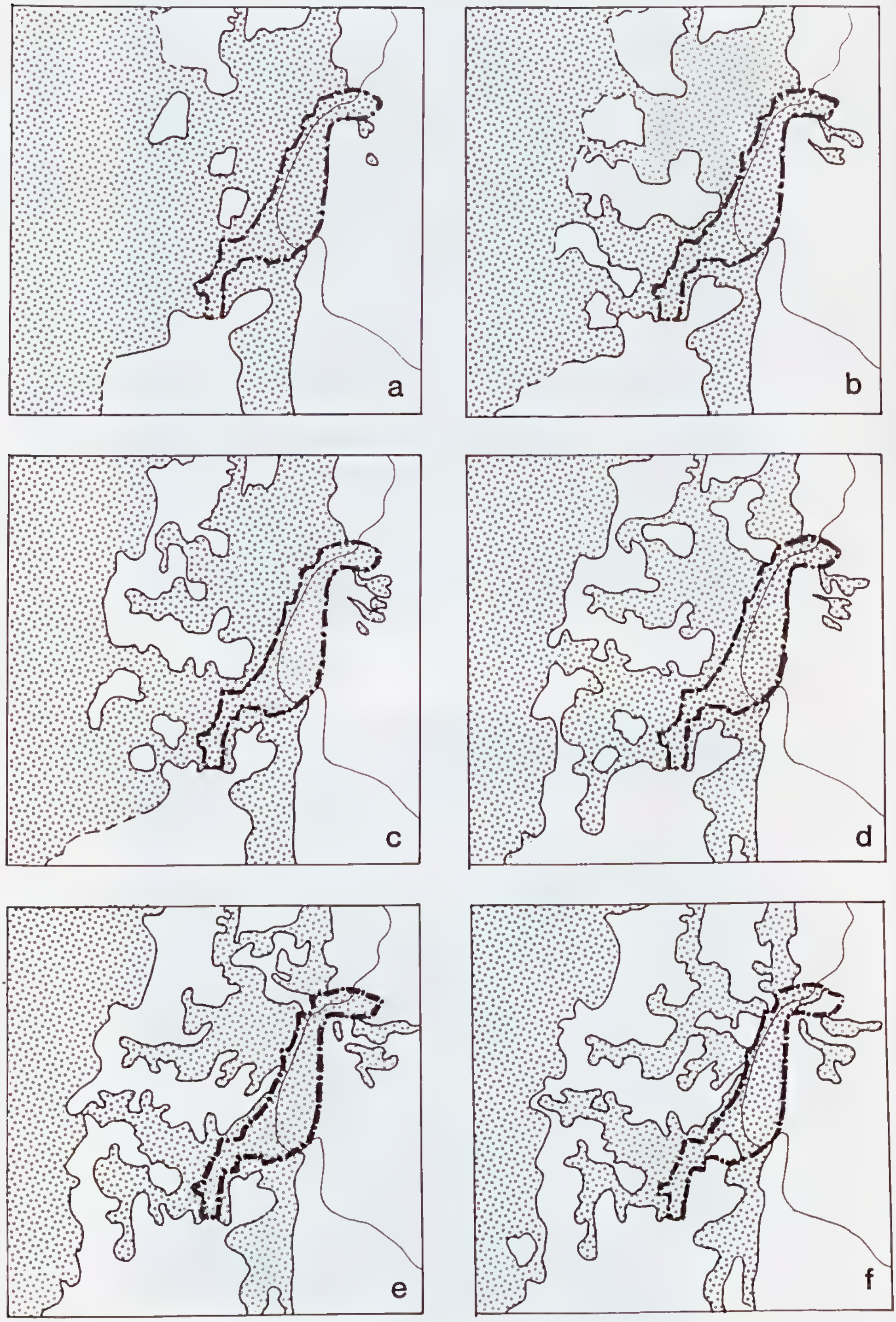

Figure 10. The gradual clearing of natural vegetation is turning Bents Basin S.R.A. into an island of native vegetation. **a** 1947, **b** 1955, **c** 1961, **d** 1972, **e** 1976, **f** 1983. On illustration hatching indicates remaining native vegetation, unmarked areas indicate cleared land, light broken line indicates undefined native vegetation boundary, light unbroken line indicates native vegetation boundary and heavy broken line indicates Bents basin S.R.A. boundary.

Exotic species

In contrast to the native component, the present exotic component of the flora (53 species) is likely to rise as exotic species from the surrounding agricultural and urban habitats move in (Gorman 1979). The type of exotic species and the extent of exotic establishment appears to depend on the type of disturbance. Most exotic species are confined to particular habitats. The 53 exotic species (Appendix II) are found in an average of only 1.7 communities, though some species occur in up to 8 communities. These species may be widespread but not necessarily aggressive. Invasion by exotic species appears to be associated mainly with boundaries and watercourses. Boundary effects, related to the proportion of perimeter to area, will generally be more significant in small areas (Buchanan 1979, Benson & Keith 1984). The long, narrow shape of Bents Basin S.R.A. makes it very vulnerable to such effects. Disturbances which promote invasion of exotic species are the addition of nutrients and sediment to watercourses, the clearing of vegetation adjacent to native bushland, floods, and to a lesser extent, fire and trampling by visitors and introduced animals. As a result, distribution of exotic species is strongly associated either with riverine habitats or with borders and tracks. Communities with many exotic species (Communities 1, 2, 20) are all associated with the Nepean River (Table 3, Appendix II).

Table 3. The number of native species, area(ha) and percentage area for each plant community in Bents Basin S.R.A.

Community	No. of native species	Area (ha)	%
1. Tall open-forest	21	1	(< 1)
2. Tall open-forest	42	4	(1)
3. Tall open-forest	31	3	(< 1)
4. Open-forest	42	7	(2)
5. Open-forest	45	20	(5)
6. Open-forest	41	16	(4)
7. Open-forest	#		(< 1)
8. Tall Woodland/Open-forest	72	40	(< 10)
9. Woodland	76	168	(43)
10. Woodland	54	60	(15)
11. Woodland	#		(< 1)
12. Woodland	82	24	(6)
13. Woodland	64	10	(3)
14. Woodland	38	3	(< 1)
15. Woodland	46	1	(< 1)
16. Woodland	14	1	(< 1)
17. Woodland	33	10	(3)
18. Woodland	#		(< 1)
19. Woodland	26	2	(< 1)
20. Woodland	15	8	(2)
21. Scrub	#		(< 1)
22. Sedge/shrubland	29	3	(< 1)
23. Grassland	8	9	(2)
24. Grassland	5		(< 1)
Total	309	391	

# no detailed sampling

Management

Bents Basin S.R.A. is a small reserve when compared with National Parks like Ku-ring-gai and Brisbane Water, but because of its location near Sydney's growing western suburbs it will come under increasing pressure from bushwalkers, campers and other visitor groups. Horse-riding in Ku-ring-gai Chase National Park has caused erosion of tracks and invasion by exotic species (S. King pers. comm.) and could do so at Bents Basin. Invasion by cattle from nearby pastoral land has caused soil compaction, selective grazing of herb and shrub layers and invasion by exotic species. A succession of frequent fires may also lead to changes in species composition, and the risk of invasion by exotic species. Enlightened management of fire, exotic species, introduced animals and recreation will be needed if the present rich native flora, including the rare and interesting species in Bents Basin S.R.A., is to survive. In the long-term such management needs to be supported by ongoing research and monitoring. In the short-term plant community and habitat diversity need to be maintained. The approach here therefore has been to recognize as much of the variation in plant communities as possible. Future work may show that some units are the same and only apparently different because of past management treatments, e.g. different fire regimes. In the absence of detailed knowledge of the processes in plant communities, it is safest to assume that observed differences are intrinsic features of the vegetation.

Acknowledgements

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Appendix 1

List of native species recorded for Bents Basin State Recreation Area in 1988.

There were 362 species from 87 families recorded during the survey. The numbers of those species from the major taxonomic groups are as follows:

Group	Number of species	Number of exotic species	Number of families
Pteridophytes	16		9
Gymnosperms	1		1
Angiosperms			
Monocotyledons	80	10	16
Dicotyledons	265	43	61
Total	362	53	87

The floristic list is arranged hierarchically: alphabetically for species, genera and families, and systematically for higher groups.

All names are as in Jacobs, S. and Pickard, J. (1981). (Plants of New South Wales, New South Wales Government Printer), except those instances where the National Herbarium of New South Wales has since adopted other names.

Exotic species are prefixed by an asterix (*).

The numbers in the columns on the right hand side of the table show the communities in which each species was found.

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Dicotyledons																								
ACANTHACEAE																								
Brunoniella australis					5																			
Brunoniella pumilio					5	6						12		14	15									
Pseuderanthemum variabile			3																					
ACERACEAE																								
**Acer negundo*																				20				
AMARANTHACEAE																								
Alternanthera denticulata				4												16								
Nyssanthes diffusa																	17							
ANACARDIACEAE																								
**Schinus areira*																								24
APIACEAE																								
**Apium leptophyllum*		2																						
**Foeniculum vulgare*	1																							
Hydrocotyle acutiloba			3																					
Hydrocotyle peduncularis					5																			
Hydrocotyle sp.			3																					
Platysace ericoides									9															
Platysace lanceolata					5	6		8	9	10		12	13											
Platysace linearifolia													13											
Xanthosia pilosa								8																
ARALIACEAE																								
Astrotricha latifolia								8																
ASCLEPIADACEAE																								
**Araujia hortorum*	1									10										20				
**Gomphocarpus fruticosus*																			19					
Marsdenia rostrata				4																				
Tylophora barbata			3	4																				
ASTERACEAE																								
**Ageratina adenophora*				4																				
**Bidens pilosa*	1																		19				23	
**Bidens subalternans*										10									19				23	
Brachycome angustifolia													13				17							

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Calotis dentex			3																					
**Chondrilla juncea*	1																							
**Cirsium vulgare*		2								10									19					
**Conyza albida*	1	2	3							10		12	13		15								23	
**Conyza bonariensis*		2			5														19				23	
**Galinsoga parviflora*				4																				
**Gnaphalium americanum*		2		4	5										15									
Gnaphaliam gymnocephalum		2										12	13											
Gnaphalium involucratum		2																						
Gnaphalium sphaericum																			19					
Helichrysum bracteatum													13											
Helichrysum diosmifolium					5			8		10														
Helichrysum viscosum													13											
**Hypochaeris radicata*		2	3												15								23	
Lactuca sp.																							23	
Lagenifera stipitata					5	6																		
**Leontodon taraxacoides*					5					10			13											
Olearia microphylla										10														
Olearia viscidula										10														
Pseudognaphalium leuto-album													13											
Senecio hispidulus													13											
Senecio lautus													13											
**Senecio madagascariensis*		2			5		7						13							20			23	
**Senecio mikanioides*	1																							
Senecio sp.					5					10														
Senecio vagus																								
var. *eglandulosus*		2																						
Sigesbeckia orientalis		2																						
**Sonchus oleraceus*					5					10					15									
**Taraxacum officinale*							7					12			15					20			23	
**Tagetes minuta*		2																						
Vernonia cinerea																								
var. *cinerea*					5							12	13	14										
**Xanthium chinese*																				20				

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
BORAGINACEAE																								
Cynoglossum australe	1																							
CACTACEAE																								
**Opuntia* sp.	1																							
CAMPANULACEAE																								
Wahlenbergia gracilis		2	3		5			8		10		12	13		15					20			23	
Wahlenbergia communis												12			15									
CARYOPHYLLACEAE																								
**Polycarpon tetraphyllum*		2																		20				
Stellaria flaccida		2	3	4																				
**Stellaria media*		2																		20				
CASUARINACEAE																								
Allocasuarina littoralis													13											
Allocasuarina torulosa		2			5	6				10			13	14	15		17							
Casuarina cunninghamiana																			19	20				
CHENOPODIACEAE																								
**Chenopodium album*																	17							
Chenopodium carinatum																			19					
Einadia hastata	1																			20			23	
Einadia nutans		2																						
CONVOLVULACEAE																								
Dichondra repens		2								10			13	14										
CRASSULACEAE																								
Crassula sieberana								8		10														
CUNONIACEAE																								
Callicoma serratifolia				4																				
Ceratopetalum apetalum				4																				
Ceratopetalum gummiferum								8		10														
DILLENIACEAE																								
Hibbertia acicularis									9															
Hibbertia aspera								8						14	15		17							
Hibbertia diffusa					5	6			9	10		12			15									
Hibbertia hermanniifolia								8																

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
DROSERACEAE																								
Drosera auriculata					5																	22		
Drosera spathulata																						22		
ELAEOCARPACEAE																								
Elaeocarpus reticulatus								8																
EPACRIDACEAE																								
Acrotriche divaricata									9															
Astroloma humifusum									9					14	15									
Dracophyllum secundum				4																				
Epacris pulchella												12				16								
Epacris purpurascens var. *purpurascens*																						22		
Leucopogon lanceolatus var. *lanceolatus*										10														
Leucopogon muticus					5	6		8	9	10	11	12		14	15		17					22		
Leucopogon virgatus									9															
Lissanthe sapida									9															
Lissanthe strigosa								8	9					14	15									
Monotoca elliptica																	17							
Monotoca scoparia									9			12							19					
EUPHORBIACEAE																								
Breynia oblongifolia		2	3										13											
Glochidion ferdinandi				4															19					
Phyllanthus gasstroemii	1																		19					
Phyllanthus thymoides						6		8	9	10		12	13	14	15		17					22		
Poranthera microphylla								8					13											
FABACEAE (Subfamily Faboideae)																								
Bossiaea buxifolia															15									
Bossiaea obcordata									9			12												
Bossiaea rhombifolia								8	9			12												
Daviesia ulicifolia									9			12		14	15									
Desmodium rhytidophyllum		2			5					10														

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Desmodium varians					5							12			15									
Dillwynia retorta									9			12					17							
Dillwynia sericea									9															
Glycine clandestina		2			5	6				10		12	13	14	15		17							
Gompholobium huegelii					5	6			9			12		14										
Hardenbergia violacea					5				9	10		12	13		15									
Hovea longifolia								8	9	10														
Indigofera australis					5	6				10														
Kennedia rubicunda												12	13											
Mirbelia rubiifolia																						22		
Oxylobium ilicifolium					5				9	10		12	13				17							
Oxylobium scandens														14										
Pultenaea elliptica										10														
Pultenaea flexilis								8				12												
(Subfamily Mimosoideae)																								
Acacia binervia	1	2																					23	
Acacia decurrens												12												
Acacia elata								8																
Acacia elongata												12												
Acacia falcata					5																			
Acacia falciformis			3									12				16								
Acacia filicifolia												12												
Acacia floribunda	1									10			13	14					19					
Acacia linearifolia									9															
Acacia mearnsii												12												
Acacia parramattensis	1	2																		20			23	24
Acacia suaveolens									9															
Acacia terminalis									9			12												
Acacia ulicifolia								8	9			12												
(Subfamily Caesalpinioideae)																								
**Gleditsia triacanthos*																			19	20				
GENTIANACEAE																								
**Centaurium erythraea*		2				6																		
Centaurium spicatum						6																		

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
GERANIACEAE																								
Geranium solanderi		2																						
GOODENIACEAE																								
Dampiera purpurea								8					13											
Goodenia bellidifolia												12												
Goodenia hederacea					5	6			9			12	13	14			17							
Goodenia ovata			3																					
Goodenia paniculata																						22		
Scaevola ramosissima										10						16								
HALORAGACEAE																								
Gonocarpus longifolius								8																
Gonocarpus tetragynus												12										22		
Gonocarpus teucrioides															15	16								
HYPERICACEAE																								
Hypericum gramineum					5		7								15		17		19			22		
LAMIACEAE																								
Plectranthus parviflorus			3	4						10														
Prostanthera incana								8								16								
Prostanthera violacea								8																
LOBELIACEAE																								
Pratia purpurascens			3		5				9			12	13			16				20				
LOGANIACEAE																								
Logania albiflora								8											19					
Logania pusilla									9															
Mitrasacme polymorpha									9			12										22		
MALVACEAE																								
Modiola caroliniana		2																						
Sida rhombifolia	1	2					7								15					20			23	
MELIACEAE																								
Melia azedarach																								
var. *australasica*	1																							
MENISPERMACEAE																								
Stephania japonica																								
var. *discolor*		2		4																				

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
MYRTACEAE																								
Austromyrtus tenuifolia																			19					
Angophora costata								8	9	10		12												
Angophora subvelutina		2	3																					
Backhousia myrtfolia	1		3					8															23	
Callistemon salignus				4															19					
Eucalyptus agglomerata								8																
Eucalyptus benthamii	1																							
Eucalyptus crebra					5									14										
Eucalyptus deanei		2	3																					
Eucalyptus elata	1	2																						
Eucalyptus eugenioides					5	6			9			12	13	14	15			18						
Eucalyptus eximia					5	6			9			12	13									22		
Eucalyptus fibrosa subsp. *fibrosa*													13	14	15									
Eucalyptus gummifera					5			8	9	10		12		14				18						
Eucalyptus maculata															15	16								
Eucalyptus notabilis																		18						
Eucalyptus pilularis						6		8	9	10		12					17	18						
Eucalyptus punctata					5	6			9	10		12	13	14	15		17							
Eucalyptus oblonga (sparsifolia)																					21			
Eucalyptus tereticornis							7																	
Kunzea ambigua																					21	22		
Leptospermum attenuatum								8	9			12					17							
Leptospermum flavescens				4																	21	22		
Melaleuca styphelioides																				20				
Melaleuca thymifolia																						22		
Syncarpia glomulifera				4		6		8	9			12		14			17							
Tristaniopsis laurina				4															19					
MYRSINACEAE																								
Rapanea variabilis			3					8																
OLEACEAE																								
**Ligustrum sinense*																			19	20				

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Notelaea longifolia				4				8																
**Olea europaea*																								
subsp. *africana*			3				7						13							20				
PASSIFLORACEAE																								
**Passiflora edulis*				4																				
**Passiflora subpeltata*			3																					
PHYTOLACCACEAE																								
**Phytolacca octandra*				4																				
PITTOSPORACEAE																								
Billardiera scandens									9								17							
Bursaria spinosa		2											13											
Pittosporum revolutum			3																					
PLANTAGINACEAE																								
Plantago debilis				4																				
**Plantago lanceolata*					5		7																	
POLYGALACEAE																								
Comesperma sp.									9															
POLYGONACEAE																								
**Acetosella vulgaris*		2																						
Persicaria decipiens																16								
Persicaria hydropiper																			19					
Persicaria lapathifolia				4																				
PORTULACEAE																								
Calandrinia pickeringii								8																
PROTEACEAE																								
Banksia spinulosa																								
var. *spinulosa*								8	9	10							17					22		
Conospermum longifolium								8	9															
Grevillea linearifolia												12												
Grevillea mucronulata								8				12			15									
Hakea dactyloides									9													22		
Hakea sericea																16	17							
Isopogon anemonifolius									9															
Lambertia formosa								8	9															

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Lomatia myricoides																			19					
Lomatia silaifolia								8	9	10							17							
Persoonia laevis									9			12					17							
Persoonia linearis			3		5	6		8	9	10	11	12	13	14	15		17					22		
Petrophile pedunculata									9															
Stenocarpus salignus				4																				
Xylomelum pyriforme									9			12					17							
RANUNCULACEAE																								
Clematis aristata	1	2	3																					
Clematis glycinoides	1							8									17							
Ranunculus inundatus				4																				
RHAMNACEAE																								
Pomaderris aspera		2																						
Pomaderris intermedia								8																
ROSACEAE																								
Rubus parvifolius																				20				
RUBIACEAE																								
Asperula conferta					5															20				
Morinda jasminoides				4															19					
Opercularia aspera var. *aspera*				4																				
Opercularia diphylla						6										16								
Pomax umbellata					5	6		8	9	10		12	13	14	15							22		
RUTACEAE																								
Boronia ledifolia									9			12												
Correa reflexa								8																
Eriostemon myoporoides																			19					
Phebalium squamulosum								8																
Zieria compacta								8																
Zieria cytisoides								8	9															
SANTALACEAE																								
Exocarpos cupressiformis			3		5					10			13							20				
Exocarpos strictus						6			9			12												
Leptomeria acida									9							16	17							

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Omphacomeria acerba									9															
Santalum obtusifolium									9															
SCROPHULARIACEAE																								
Veronica plebeia		2	3							10										20				
**Verbascum virgatum*													13											
SOLANACEAE																								
Solanum campanulatum													13											
**Solanum chenopodioides*	1	2			5								13							20				
Solanum nodiflorum		2																						
Solanum prinophyllum		2	3			6				10		12	13											
**Solanum pseudocapsicum*																				20				
Solanum sp.												12	13											
STERCULIACEAE																								
Lasiopetalum ferrugineum var. *ferrugineum*								8																
Lasiopetalum ferrugineum var. *cordatum*								8																
Rulingia pannosa												12												
STACKHOUSIACEAE																								
Stackhousia viminea												12	13	14	15									
STYLIDIACEAE																								
Stylidium graminifolium										10														
Stylidium laricifolium			3					8																
THYMELAEACEAE																								
Pimelea linifolia						6			9			12		14			17							
ULMACEAE																								
**Celtis occidentalis*																				20				
Trema aspera								8				12												
URTICACEAE																								
Urtica incisa	1																							
VERBENACEAE																								
Clerodendrum tomentosum		2						8																
**Verbena bonariensis*	1	2																		20				24

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
VIOLACEAE																								
Hybanthus monopetalus						6			9	10			13				17							
Hymenanthera dentata	1																			20				
Viola hederacea				4																				
VITACEAE																								
Cayratia clematidea	1	2	3																					
Monocotyledons																								
ANTHERICACEAE																								
Caesia parviflora												12												
Caesia vittata									9				13											
Laxmannia gracilis									9			12		14			17							
Thysanotus juncifolius												12		14								22		
Tricoryne elatior						6																		
ASPARAGACEAE																								
**Asparagus asparagoides*	1																			20				
**Asparagus officinalis*		2																		20				
COMMELINACEAE																								
Commelina cyanea	1	2																					23	
**Tradescantia albiflora*	1		3																	20				
CYPERACEAE																								
Carex appressa		2																						
Caustis flexuosa									9			12												
**Cyperus eragrostis*																			19					
Cyperus gracilis										10														
Cyperus laevis		2								10			13											
Cyperus trinervis				4																				
Gahnia aspera		2											13											
Lepidosperma laterale					5	6		8	9				13	14	15	16								
Schoenus apogon								8																
Schoenus melanostachys				4				8																
DIANELLACEAE																								
Dianella caerulea			3					8				12	13		15									
Dianella laevis								8																
Stypandra glauca										10		12				16						22		

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
HAEMODORACEAE																								
Haemodorum sp.																						22		
JUNCACEAE																								
Juncus articulatus																			19					
Juncus continuus																			19					
HYPOXIDACEAE																								
Hypoxis hygrometrica					5											14	15							
LOMANDRACEAE																								
Lomandra confertifolia subsp. *rubiginosa*								8				12				16								
Lomandra filiformis subsp. *coriacea*					5							12												
Lomandra fluviatilis																			19					
Lomandra longifolia	1	2				6		8	9	10		12							19			22		
Lomandra multiflora					5			8	9															
Lomandra obliqua						6		8	9	10		12		14			17					22		
ORCHIDACEAE																								
Bulbophyllum exiguum				4																				
Dendrobium linguiforme				4				8																
Dendrobium pugioniforme				4																				
Dendrobium speciosum				4				8																
Dipodium punctatum												12												
Diuris sp.						6																		
Liparis reflexa				4																				
Pterostylis acuminatum						6			9															
Pterostylis parviflora								8																
Thelymitra sp.									9															
PHILESIACEAE																								
Eustrephus latifolius				4																				
Geitonoplesium cymosum			3																					
POACEAE																								
Anisopogon avenaceus		2							9		11											22		
Aristida benthamii						6			9			12					17					22		
Aristida vagans					5	6						12	13	14	15									

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
**Axonopus affinis*												12			15		17		19					
Cymbopogon refractus		2			5	6				10		12	13	14	15									
**Cynodon dactylon*	1	2																					23	
Danthonia sp.								8																
Dichelachne crinita										10		12			15									
Dichelachne micrantha												12												
Dichelachne rara												12												
Digitaria parviflora						6				10			13											
Digitaria ramularis					5																			
Dimorphochloa rigida									9	10														
Echinopogon caespitosus					5	6				10			13	14	15									
Entolasia stricta					5	6		8	9	10		12	13		15									
Entolasia marginata									9					14								22		
Eragrostis brownii						6			9				13				17							
Eragrostis leptostachya		2												14	15									
Imperata cylindrica		2								10		12	13											
**Lolium rigidum*																								24
Microlaena stipoides			3										13				17							
Oplismenus imbecillis	1		3							10									19					
Panicum simile						6			9			12		14										
Paniucum sp.					5							12			15									
**Paspalum dilatatum*																				20				24
**Phalaris minor*																								24
**Setaria geniculata* var. *pauciseta*	1	2											13						19	20			23	
Stipa pubescens												12												
Stipa ramosissima		2	3																					
Stipa sp.			3																					
Themeda australis		2			5					10	11	12	13	14	15					20		22		
RESTIONACEAE																								
Lepyrodia muelleri																						22		
SMILACEAE																								
Smilax glyciphylla				4																				

ANGIOSPERMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
TYPHACEAE																								
Typha sp.								8																
XANTHORRHOEACEAE																								
Xanthorrhoea arborea								8																
Xanthorrhoea minor						6			9	10		12					17					22		
GYMNOSPERMS																								
ZAMIACEAE																								
Macrozamia spiralis						6																		
PTERIDOPHYTA																								
ADIANTACEAE																								
Adiantum aethiopicum			3	4															19					
Adiantum hispidulum				4															19					
Cheilanthes distans		2			5	6				10			13											
Cheilanthes sieberi												12		14	15									
Pellaea falcata		2		4																				
ASPLENIACEAE																								
Asplenium flabellifolium								8																
BLECHNACEAE																								
Blechnum cartilagineum								8																
Doodia aspera			3																					
Doodia caudata																			19					
CYATHEACEAE																								
Cyathea australis				4																				
Culcita dubia				4																				
DAVALLIACEAE																								
Davallia pyxidata				4																				
DENNSTAEDTIACEAE																								
Pteridium esculentum	1			4				8		10		12							19					
GLEICHENACEAE																								
Sticherus flabellatus				4																				
LINDSAEACEAE																								
Lindsaea microphylla				4				8														22		
OSMUNDACEAE																								
Todea barbara				4																				

Appendix 2

Exotic species recorded in Bents Basin State Recreation Area in 1984.

Abundance (column 3)
+ distribution limited within one community and/or a few individuals recorded in the S.R.A.
++ scattered distribution throughout the S.R.A.
+++ Common throughout the S.R.A.
++++ Very common or scattered distribution but intense infestation (i.e. **Tradescantia albiflora*)

Distribution (column 4)
R Riverine associated
B Border or track associated

FAMILY, species	Common Name	Abundance	Distribution
Dicotyledons			
ACERACEAE			
**Acer negundo*	Box-elder Maple	+	R
ANACARDIACEAE			
**Schinus areira*	Pepper Tree	+	B
APIACEAE			
**Apium leptophyllum*	Slender Celery	+	R
ASCLEPIADACEAE			
**Araujia hortorum*	White Moth Vine	+	R
**Gomphocarpus fruticosus*	Narrow-leaved Cotton Bush	+	R
ACTERACEAE			
**Ageratina adenophora*	Crofton Weed	+	R
**Bidens pilosa*	Cobblers Peg	++	R,B
**Bidens subalternans*		++	R,B
**Chondrilla juncea*	Skeleton Weed	+	R
**Cirsium vulgare*	Spear Thistle	+	R
**Conyza albida*	Tall Fleabane	++++	R,B
**Conyza bonariensis*	Flax-leaved Fleabane	++++	R,B
**Galinsoga parviflora*	Potato Weed	+	R
**Gnaphalium americanum*	Cudweed	+++	R,B
**Hypochoeris radicata*	Catsear	++	R,B
**Leontodon taraxicoides*		++	B
**Senecio madagascariensis*	Fireweed	++++	R,B
**Senecio mikanioides*	Cape Ivy	+	R
**Sonchus oleraceus*	Common Sowthistle	++	B
**Taraxacum officinale*	Dandelion	+++	B
**Tagetes minuta*	Stinking Roger	+	R
**Xanthium chinense*	Noogoora Burr	+	R
CACTACEAE	Prickly Pear	+	R
**Opuntia sp.*			
CARYOPHYLLACEAE			
**Polycarpon tetraphyllum*	Four leaf All-seed	+	R
**Stellaria media*	Chick Weed	+	B
CHENOPODIACEAE			
**Chenopodium album*	Fat-hen	+	B
FABACEAE			
**Gleditsia triacanthos*	Honey Locust	++	R
GENTIANACEAE			
**Centaurium erythraea*	Common Centaury	+	R

FAMILY, species	**Common Name**	**Abundance**	**Distribution**
MALVACEAE			
**Modiola caroliniana*	Red Flowered Mallow	+	R
**Sida rhombifolia*	Paddys Lucerne	+++	R,B
OLEACEAE			
**Ligustrum sinense*	Small-leaved Privet	+++	R,B
**Olea europaea* subsp. *africana*	Wild Olive	++	R,B
**PASSIFLORACEAE*			
**Passiflora edulis*	Common Passionfruit	+	R
**Passiflora subpeltata*		+	R
PHYTOLACCACEAE			
**Phytolacca octandra*	Ink Weed	+	R
PLANTAGINACEAE			
**Plantago lanceolata*	Ribwort	++	B
POLYGONACEAE			
**Acetosella vulgaris*	Sheep Sorrel	+	B
SCROPHULARIACEAE			
**Verbascum virgatum*	Twiggy Mullein	+	B
SOLANACEAE			
**Solanum chenopodioides*			
**Solanum pseudocapsicum*	Madiera Winter Cherry	+	R
ULMACEAE			
**Celtis occidentalis*		+	R
VERBENACEAE			
**Verbena bonariensis*	Purple Top	++	B
Monocotyledons			
ASPARAGACEAE			
**Asparagus asparagoides*		+	R
**Asparagus officinalis*	Asparagus	+	R
COMMELINACEAE			
**Tradescantia albiflora*	Wandering Jew	++++	R,B
CYPERACEAE			
**Cyperus eragrostis*	Umbrella Sedge	+	R
POACEAE			
**Axonopus affinis*	Narrow-leaved Carpet Grass	+++	R,B
**Cynodon dactylon*	Common Copuch	++	B
**Lolium rigidum*	Wimmera Ryegrass	++	B
**Paspalum dilatatum*	Paspalum	++	B
**Phalaris minor*	Lesser Canary Grass	+	B
**Setaria geniculata*	Slender Pigeon Grass	+++	R,B

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Vegetation of Bouddi Peninsula, New South Wales

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Abstract

McRae, R.H.D. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1990. Vegetation of Bouddi Peninsula, New South Wales. Cunninghamia 2(2): 263–293. The results of an ecological survey of the Bouddi Peninsula, New South Wales (latitude 33°30′ S, longitude 151°20′ E), are presented. The area lies in the Central Coast botanical subdivision and includes Bouddi National Park (1160 ha). Fifteen vegetation communities are mapped, and related to habitat elements such as geology, geomorphology, climate and soil. A species list and a vegetation map (at a scale of 1:25 000) are also given. The implications of the results of the survey for the management of fire effects, weed invasion and rare or restricted species are discussed.

Introduction

The Bouddi Peninsula is situated on the northern headland of Broken Bay, 45 km north of Sydney and 10 km south-east of Gosford (Figure 1). It is near the towns of Killcare, Kincumber, MacMasters Beach and Woy Woy (Figure 1). A large portion of the Peninsula is occupied by Bouddi National Park.

The climate is typical of that of the Central Coast. Mean temperature and rainfall data (Bureau of Meteorology 1979) are shown in Table 1. The local climatic effects that influence the vegetation on the Peninsula are: (1) proximity to the coast exposes vegetation to coastal winds and salt-spray; and (2) high areas with a coastal aspect receive the most rainfall.

The geology of the area has been described in Herbert & Helby (1980; especially articles 10 and 12) and in Strom, Goldstein & Strom (1979). The main components are two nearly level-bedded Triassic sedimentary series: the Hawkesbury Sandstone and the Narrabeen Series. The former is largely cross-bedded sandstone, with frequent interbedded shale lenses. The latter contains a wide range of sedimentary rock types, from massive sandstone to shale. The other components of the surface geology are deposits of transported material, weathered from the above rock types or deposited from the coastal long-shore drift system, and thus of variable origin. The surface geology is shown in Figure 2.

The Peninsula contains a number of landforms (Figure 3) that are important for understanding the vegetation patterns. Mount Bouddi (166 m altitude), Wards Hill and Box Head are erosional remnants of a plateau of Hawkesbury Sandstone, each generally from 0.5 km to 2.0 km across. The thickness of the cliff-lined Hawkesbury Sandstone caps ranges from about 50 m in the south to about 15 m in the north. A ridgeline capped by Hawkesbury Sandstone, 1.5 km long and 0.5 km wide, joins Wards Hill and Mount Bouddi, and is also edged

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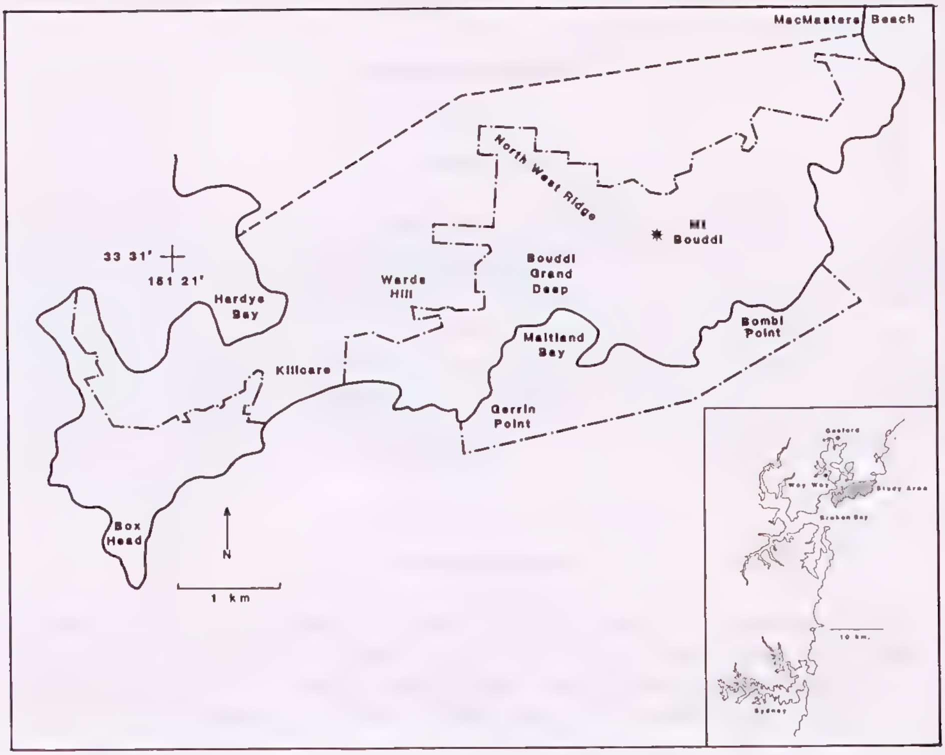


Figure 1. Location maps, showing the locations of sites and localities mentioned in the text.

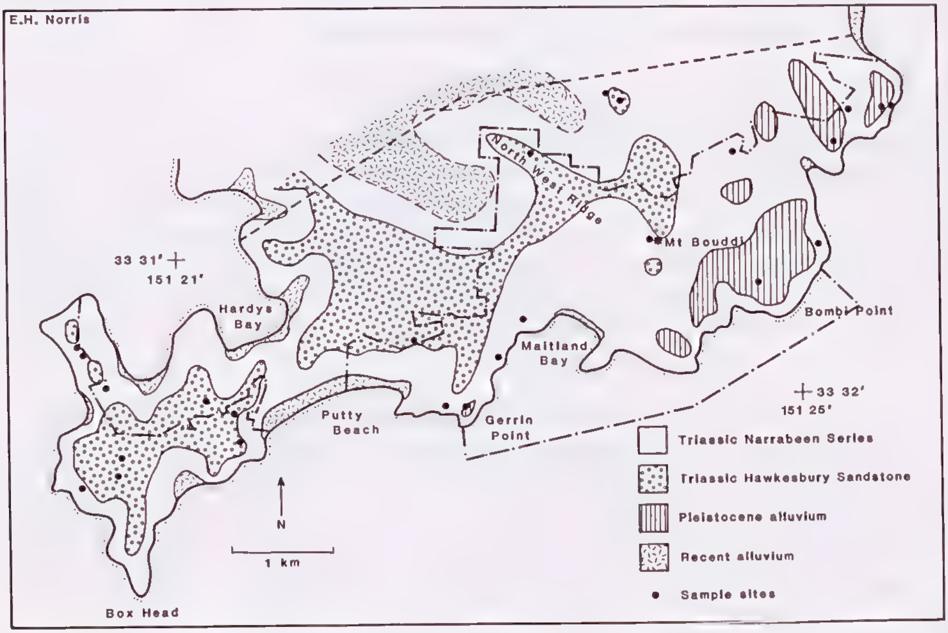


Figure 2. Surface geology of the Bouddi Peninsula and the locations of the sample sites (dots).

Table 1. Approximate mean temperature and rainfall data for Bouddi Peninsula.

Mean seasonal and annual rainfall data (mm)

Summer	Autumn	Winter	Spring	Annual
350	380	300	240	1270

Mean monthly temperature for selected months and mean annual temperature (°C)

	January	April	July	October	Annual
Maximum	26.5	22.5	17	22	22
Minimum	18	13	7.5	13	13

by small cliffs. Where the sandstone is thinnest, such as around the top of the Bouddi Grand Deep, it is broken up by undercutting and often forms a colluvial layer above the rocks downslope.

The Box Head and Wards Hill plateaus are fringed by steep slopes on the Narrabeen Series strata. The slope varies with local rock type, but frequently exceeds 30°. No true gullies have developed here, and drainage basins tend to have an amphitheatre shape, a width of about 0.5 km and numerous drainage lines. There are also steep slopes to the north-east, but gullies are present, leading to greater variation in landform. The drainage basins are about 1.5 km long and 0.5 to 1.5 km wide, and the main stream directions appear to be joint-controlled. Most of these streams have a number of short steep side branches, many slightly incised and with headwaters on Hawkesbury Sandstone.

Coastal erosion of the Narrabeen Series often proceeds preferentially along joint-lines, producing large straight cliffs. Features associated with these include occasional super-littoral talus deposits, numerous broad wave-cut platforms and small coves where streams, often spring-fed, reach the coast. The presence of beaches backed by small cliffs, as at Maitland Bay, suggests that coastal erosion may have slowed, but west of Bombi Point is a cove that is evidently being actively enlarged.

The perched Pleistocene dunes tend to lie south-east of a line from Gerrin Point to MacMasters Beach, and appear to have covered a series of gullies on the Narrabeen Series strata (Figure 2). The marking of the south-eastern edge of this area by sea cliffs and the tendency of the dunes to slope towards the coast suggests that they are being eroded away on their coastal sides. In places springs emerge from under the dunes and flow into abrupt, deep gullies.

There are four soil types derived from the Narrabeen Series strata near the coast, all of which are heterogeneous, reflecting the variation in parent material. One is a talus deposit at the foot of the coastal cliffs ('super-littoral' deposits), with soils developing in situ, mainly through weathering of shales, pulverising of falling rocks and transporting of soils from above in the talus. The disruption of soils above cliff-lines and rock-ledges caused by coastal erosion leads to a soil that is very similar to the super-littoral talus. Another skeletal soil develops on the steep slopes above the headlands. The gullies often have small, waterlogged alluvial deposits.

Several different soils develop away from the coast, ranging from sandy and skeletal soils derived from sandstone to soils derived from shale that are deeper, higher in clay content and richer in nutrients. All of these soils are

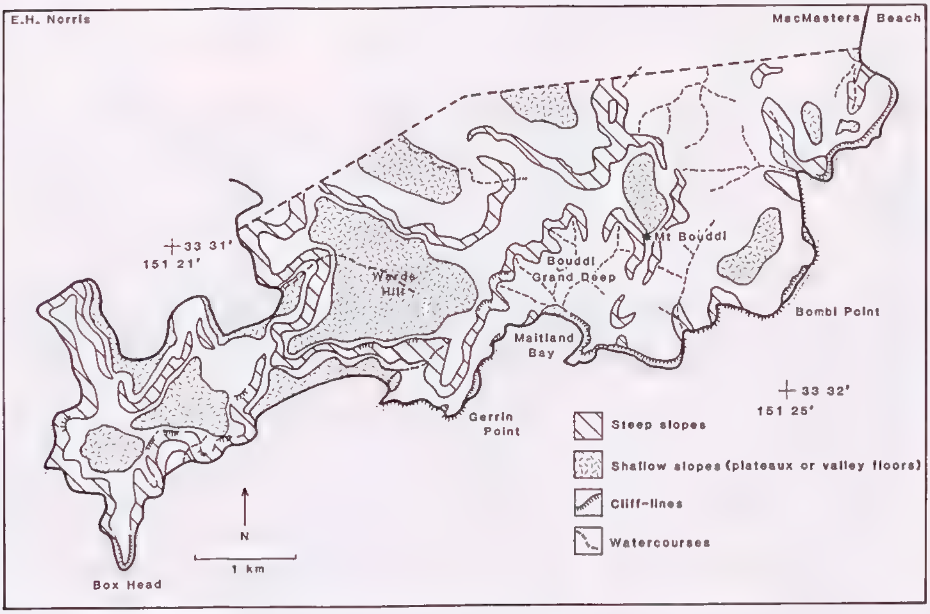


Figure 3. Major landforms on the Bouddi Peninsula. Based on aerial photograph interpretation.

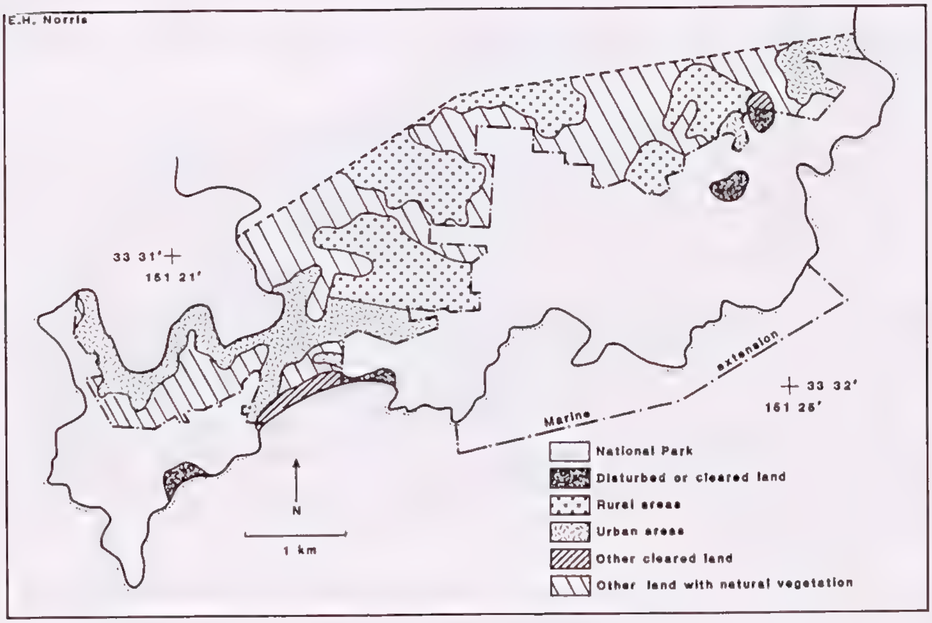


Figure 4. Major land uses on the Bouddi Peninsula.

associated with active erosion, and most include some material of colluvial origin.

There are three soil types derived from the Hawkesbury Sandstone. One is a 'laterite' in the sense used by Hunt, Mitchell & Paton (1977); the surface exposure of this ranges from a rich orange clay to a thick indurated ironstone. Another is a group of typical sandstone soils: gradational sandy soils, and duplex soils with clay subsoils derived from shale lenses interbedded in the sandstone. The third soil type is that associated with the edges of the Hawkesbury Sandstone plateaus: rocks from the plateau edges transported downslope as colluvium trap soil and humus. Although rocks of the Narrabeen Series underly this soil, they appear to contribute little to it.

A podsol, developed on the aeolian Pleistocene sands, has two main horizons: a leached A-horizon, which is very deep (in places apparently over 20 m) and an indurated B-horizon containing a pan cemented by iron and organic matter. Where the unconsolidated A-horizon has been removed, the B-horizon often persists.

The Recent alluvial soils are of two types. The beaches and hind-dunes are generally of undifferentiated sand. Podsolization is not evident, and there are no areas intermediate with the Pleistocene dunes. The alluvial deposits fringing Brisbane Water are infilled mud-basins (Chapman et al., 1982). The soils vary in depth, composition and salinity with distance from the estuary.

The history of Bouddi National Park and surrounding areas is described in Strom et al. (1979). The clearing of natural bushland on the Peninsula has mainly been for housing or small farms, with scattered clearing for other purposes. Housing generally occupies flat or scenic areas, such as Hardys Bay, Pretty Beach or Killcare. There are small orchards on the lateritic soils on Wards Hill and small hobby farms on the slopes and alluvial flats facing Brisbane Water. Except for some areas around Mount Bouddi and Box Head, almost all land has been either developed or included in Bouddi National Park. The distribution of major land-use classes is shown in Figure 4.

The vegetation of the Bouddi Peninsula has been relatively poorly studied compared with other areas close to Sydney. Work done here includes a series of studies on the ecology of the moors or heathlands (Siddiqi 1971; Siddiqi, Carolin & Anderson 1972; Siddiqi & Carolin 1976; and Siddiqi, Carolin & Myerscough 1976). Benson (1980) covered the Peninsula as part of a general vegetation mapping program working at a scale of 1:100 000. The wide-ranging ecological study of the vegetation of the Sydney basin by Pidgeon (1937, 1938, 1940 & 1941) has some relevence to this area, although her work was quite general. Strom et al. (1979) provided a general description of the Park. The topics of detailed vegetation description and discussion of management implications have not, to date, been addressed.

The plants in the area rely on a wide range of reproductive strategies to recover after fire. General discussion of these strategies can be found in Gill (1981), Groves (1981), Noble & Slatyer (1981) and Stanbury (1981). Siddiqi (1971), Siddiqi, Carolin & Myerscough (1976) and Strom et al. (1979) have briefly considered the effects of fire on the vegetation in the Park. Although the nature of this study precluded any detailed analysis of fire effects, any that were apparent were recorded and their importance for management of the area considered.

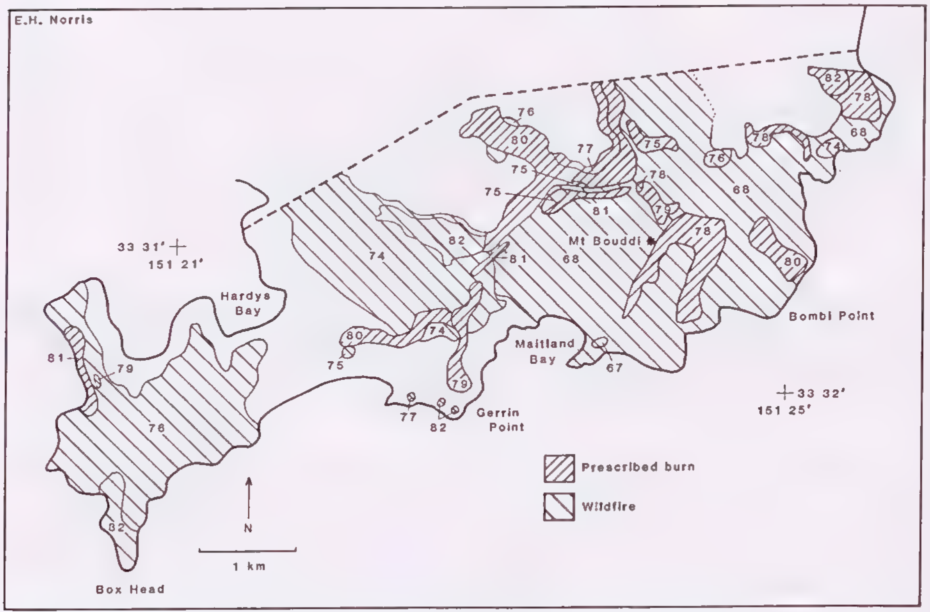


Figure 5. Fire history of the Bouddi Peninsula up to 1983, showing extent and year of fires. Based on office records of National Parks and Wildlife Service.

The fire history of the area is shown in Figure 5. Three large wildfires, in 1968, 1974 and 1976, have together burnt most of the Peninsula. Since these fires there have been many (almost 30) smaller fires, about half of which have been prescribed burns.

Studies in urban bushland in Sydney (Clements 1983 and Adamson & Buchanan 1974) and general reviews of exotic species in Australia (such as Michael 1981) are useful for interpreting local patterns. Data on weed invasion in the far northern suburbs of Sydney (McRae, Cooper & Benson 1981) suggest that weeds will generally cross from cleared or disturbed land into adjacent bushland at a rate that varies with land-use, land-form and the age of the disturbances. Further, movement of nutrient in run-off down watercourses will lead to weed spread down-stream and, more slowly, away from the watercourse.

The conservation of rare or restricted species is becoming a critical issue for the managers of public lands. With continuing land clearance and land degradation the need for conservation-oriented management is increasing. While the collection of a large quantity of data is needed for fully informed management, this was not practicable in this study. However, general data from ecological surveys such as this can complement those from taxonomic collections and form a useful initial knowledge-base.

The aims of the analysis of the vegetation of the Peninsula were to relate the various identifiable combinations of structure and floristic composition to variations in habitat and to identify any factors relevant to the management of the vegetation.

Methods

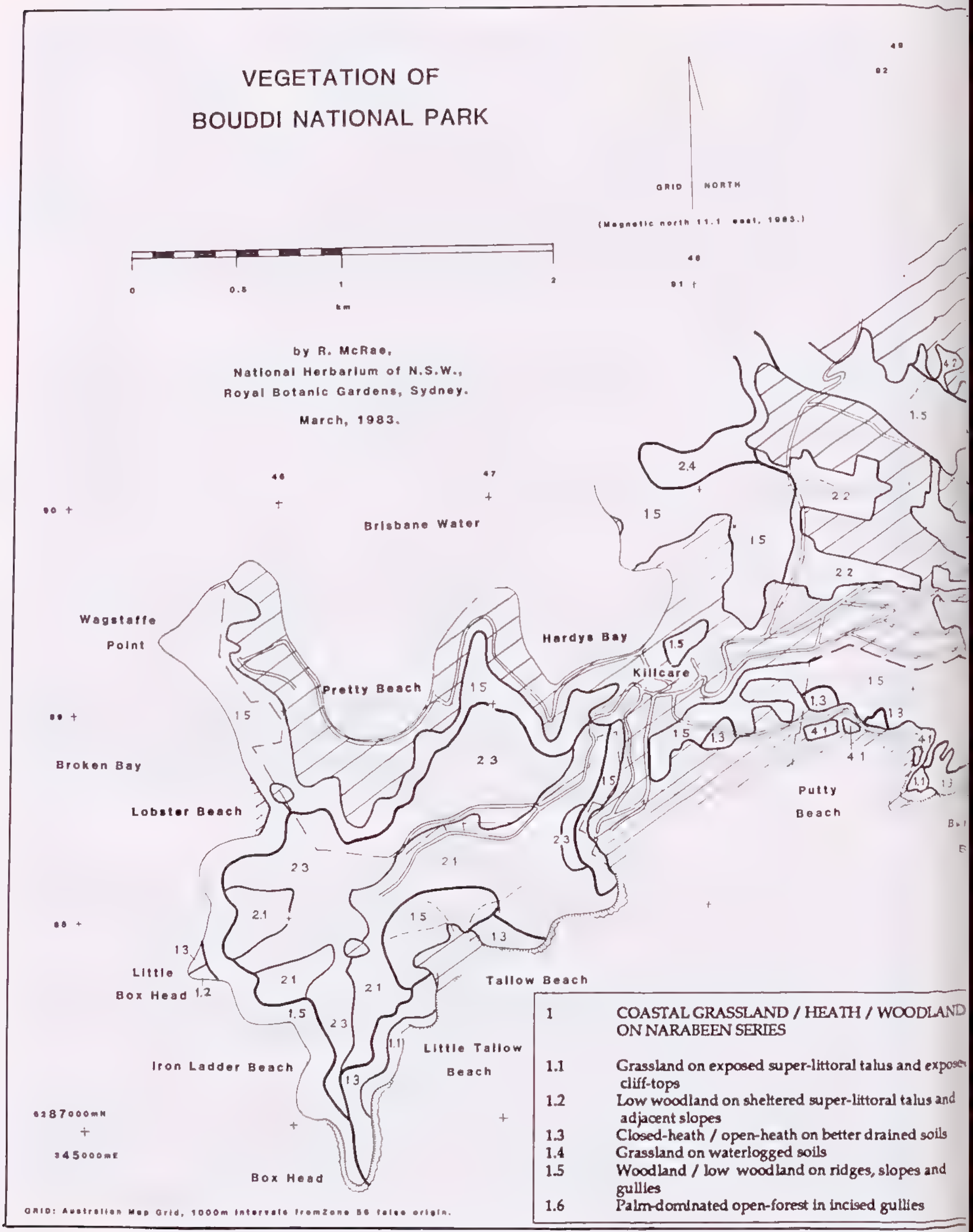
A series of sample sites was used to collect data on vegetation structure and floristics, and on the habitat. The data from these were sorted to identify vegetation patterns at two scales. Firstly, patterns in the vegetation that were identified and related to corresponding patterns in the habitat form map units that equate with vegetation communities. Secondly, the map units were grouped together on the basis of their geology. This grouping was chosen because geology correlates well with soil and geomorphology (and was readily mapped), and because it allows comparison with other work. Recent mapping around the Sydney area, usually at a smaller scale than the present work (e.g. Benson 1980), has treated geology as a major factor associated with local vegetation patterns.

The locations of the 26 sample sites are shown in Figure 2. They were each circular and 400 m^2. They were determined after preliminary field reconnaissance, to achieve a balance between the need for replication and adequate sampling of the full range of vegetation present. However, for some minor map units, field notes only were collected. At each site the following data were collected: (i) physiography (location, aspect, slope, elevation, geology, soil, drainage anomalies and a site sketch); (ii) the vegetation structure (height and projective foliage cover for each distinct stratum present); (iii) species present (height and cover); (iv) an index of abundance of each life-form present; (v) any evidence relating to the life history of significant species; and (vi) site disturbance. A species list for Bouddi National Park was prepared from these data and from other reliable sources (see Appendix). This list shows observed growth habits and the community groups in which the species occurred. The vegetation was mapped at a scale of 1:25 000. This scale was selected as the smallest commonly used that would permit display of detail to a resolution of 100 m. The mapping was based on interpretation of aerial photography (New South Wales Department of Lands 1975). Structural terminology is that of Specht (1970).

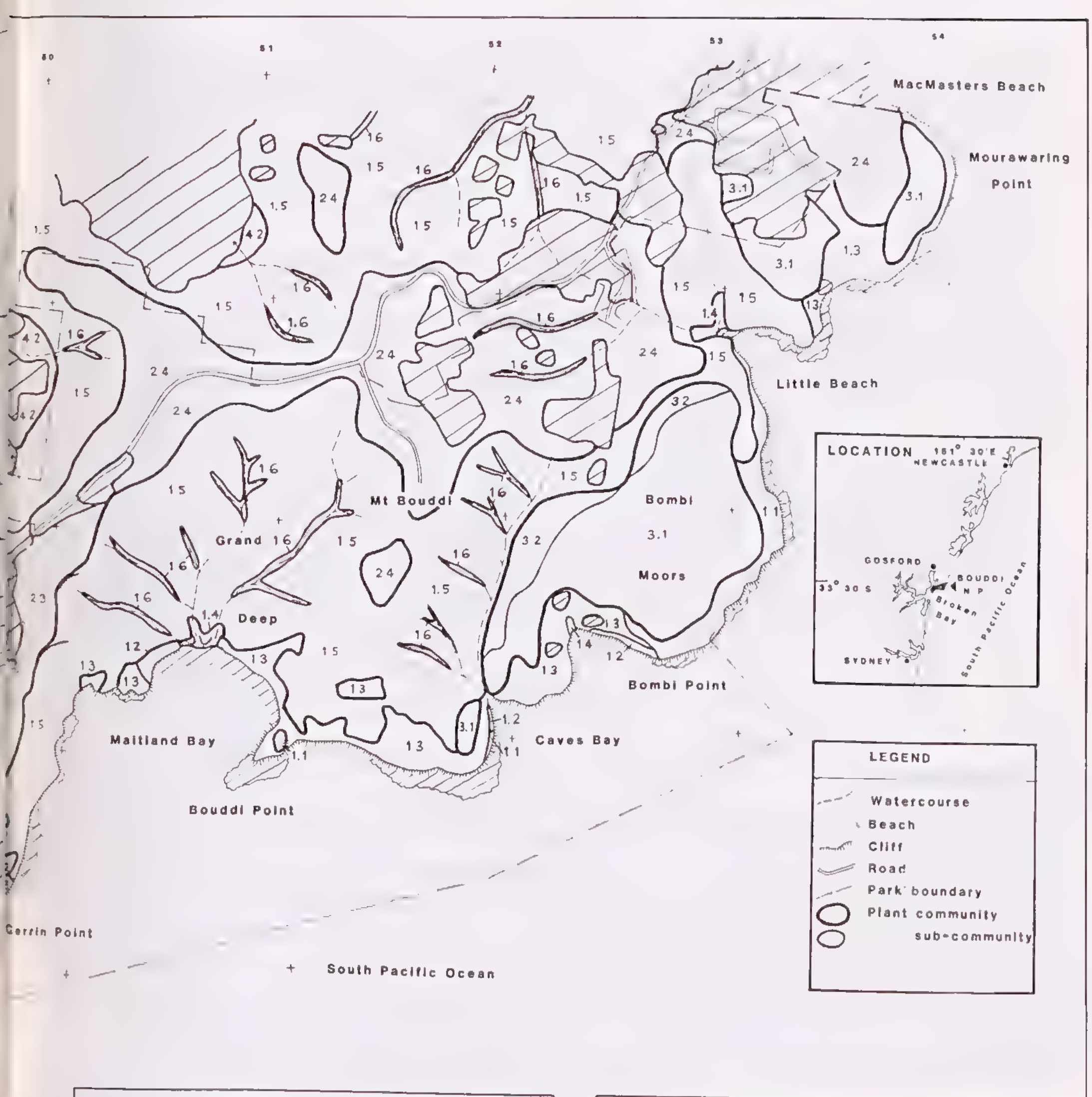
No quantitative methods were used for examining fire effects. General field reconnaissance was used for examination of broad-scale patterns, while detailed notes were taken at the quadrats if any fire effects were apparent. The fire history records held by the National Parks and Wildlife Service were consulted.

Local evidence was collected by general field reconnaissance and by a detailed study of spread across the urban/bushland interface. Here the total cover of all weeds and the distribution of each weed species downslope, along a transect, taken from the urban edge were recorded. The length of the transect, running from the edge of urban development until the weed problem was seen to have ended, was divided into two-metre segments. A rough elevation profile was also prepared to aid in interpretation. Projected foliage cover, and species presence/absence were recorded for each segment. The field reconnaissance included collection of notes on the disturbance history of sites at which weeds were found and comments on their frequency of occurence.

Data from the National Herbarium of New South Wales provided initial information on the distributions of rare species on the Peninsula. Further information was collected on their distribution, abundance, life histories and fire responses during detailed field reconnaissance. No quantitative procedures were used.


VEGETATION OF
BOUDDI NATIONAL PARK
GRID NORTH
(Magnetic north 11.1 east, 1983.)
0
0.5
1
2
km
by R. McRae,
National Herbarium of N.S.W.,
Royal Botanic Gardens, Sydney.
March, 1983.
Brisbane Water
Wagstaffe Point
Pretty Beach
Hardys Bay
Killcare
Broken Bay
Lobster Beach
Little Box Head
Tallow Beach
Putty Beach
Iron Ladder Beach
Little Tallow Beach
Box Head
6287000mN
345000mE
GRID: Australian Map Grid, 1000m intervals from Zone 56 false origin.
1 COASTAL GRASSLAND / HEATH / WOODLAND ON NARABEEN SERIES
1.1 Grassland on exposed super-littoral talus and expose cliff-tops
1.2 Low woodland on sheltered super-littoral talus and adjacent slopes
1.3 Closed-heath / open-heath on better drained soils
1.4 Grassland on waterlogged soils
1.5 Woodland / low woodland on ridges, slopes and gullies
1.6 Palm-dominated open-forest in incised gullies

Map 1. Vegetation areas of Bouddi Peninsula.



2	OPEN-HEATH / WOODLAND ON HAWKESBURY SANDSTONE
2.1	Low shrubland / open-heath on coastal plateaus
2.2	Woodland / open-heath on laterised soils
2.3	Woodland / open-heath on plateau soils
2.4	Woodland / on colluvial soil

3	OPEN-HEATH / LOW OPEN-WOODLAND ON PLEISTOCENE ALLUVIUM
3.1	Open-heath on coastal podsoils (A-horizon)
3.2	Low open-woodland on coastal podsoils (B-horizon)
4	TALL SHRUBLAND / WOODLAND ON PLEISTOCENE ALLUVIUM
4.1	Tall shrubland on coastal sand deposits
4.2	Woodland on estuarine alluvium

Results

Vegetation

Fifteen map units were recognized. Although classified by vegetation, these were associated with geology, geomorphology, soil and the coastal influences on the Peninsula's climate. The map units may be equated to plant communities. They have been grouped on the basis of geology. The species list is given in the Appendix and the distribution of the map units is shown in Map 1.

Group 1: Coastal grassland/heath/woodland on Narrabeen Series

This group includes all of the vegetation growing on the slopes and ridges formed on the Narrabeen Series rocks. The sites here form a series from very exposed 'super-littoral' situations to sheltered gullies away from strong coastal influences. Coastal sites, exposed to strong winds and salt spray, support mainly grasslands and closed-heath, and also occasional low open-woodland. Sheltered sites support mainly woodland and occasional open-forest.

1.1 Grassland on exposed super-littoral talus and exposed cliff-tops

This occurs above areas of strong wave action, where landslides leave a talus deposit immediately above the littoral zone, and along cliff-tops where undercutting leads to reworking of the soil. The grassland is dominated by *Themeda australis*, which forms a stratum up to 0.2 m high and of over 70% cover. In places a stratum of up to 1.0 m height is formed by shrubs such as *Westringia fruticosa*, *Banksia integrifolia* and *Baeckea imbricata*, graminoids such as *T. australis*, *Lomandra longifolia* and *Isolepis nodosa*, the ferns *Gleichenia dicarpa* and **Cyrtomium falcatum*[1] and the herbs *Apium prostratum* and *Carpobrotus glaucescens.*

1.2 Low woodland on sheltered super-littoral talus and adjacent slopes

A low woodland grows on areas of super-littoral talus and adjacent undercut slopes away from strong coastal exposure. The canopy is formed by a tall shrub layer, mostly 5–8 m high and with 30% cover, with *Banksia integrifolia* and, often, *Allocasuarina distyla* (Figure 6). The understorey in most sites has been altered by weed invasion, with species such as **Chrysanthemoides monilifera* and **Lantana camara* crowding out *Lomandra longifolia*, *Smilax glyciphylla*, *Kennedia rubicunda*, *Themeda australis* and *Acacia longifolia* var. *sophorae.* The last species is native here, but planted elsewhere on the Peninsula.

1.3 Closed-heath/open-heath on better-drained soils

This vegetation grows on coastal headlands under conditions of severe exposure to coastal winds (Figure 7). The steep slopes cutting across the various strata of the Narrabeen Series lead to considerable variation in bedrock and thus soil, but typically the soil is relatively well-drained and clayey and supports a closed-heath. Within this unit fire is an important cause of structural and floristic variation. When unburnt for 8–9 years the community is dominated by *Allocasuarina distyla*, usually forming a stratum about 1.5 m high and 95% cover. Other species include *Hakea teretifolia*, *Banksia ericifolia* and *Lasiopetalum ferrugineum.* The ground cover stratum is poorly developed or absent. After fire the *Allocasuarina* is killed off and relies on seed for regeneration. However, for a number of years its seedlings cannot attain dominance over those of other species or with species relying on lignotubers for regrowth. During this phase the local species richness is increased (based on species counts at the sample sites), and abundant species include *H. teretifolia*, *B. ericifolia*, *Isopogon anemonifolius*, *I. anethifolius*, *Petrophile pulchella*, *Woollsia pungens*, *Cyathochaeta diandra* and *Themeda australis.*

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[1] * indicates introduced species.

On sandy soils an open-heath or closed-heath develops. Common species in the tall shrub layer, which ranges from 0.5 m to 2.5 m tall and has a 60% cover, include *Hakea teretifolia*, *Banksia ericifolia* and *Allocasuarina distyla*. The understorey (0.2–1.0 m in height and 70% cover) contains shrubs such as *B. oblongifolia*, *Woollsia pungens* and *Leptospermum flavescens*, and graminoids such as *Themeda australis*, *Hypolaena fastigiata*, *Cyathochaeta diandra* and *Lepidosperma viscidum*. Where the soil becomes waterlogged to any degree a simpler structure, with one stratum (0.3–1.5 m; 100%), develops. The main species are then *Banksia oblongifolia*, *Mirbelia rubiifolia* and *Gahnia melanocarpa.*

The slopes immediately north of Tallow Beach support an open-heath on very steep, well drained but skeletal soil. The fire history is uncertain. The soil's shallowness and lack of structure, due to minor undercutting from wave action and a lack of talus from rock strata upslope, could be the critical habitat factor here. The main species in the single stratum (0.3–0.8 m; 50%) are shrubs such as *Allocasuarina distyla*, *Dillwynia floribunda*, *Banksia oblongifolia*, *B. ericifolia* and *Hakea teretifolia*, and graminoids such as *Lepidosperma squamatum*, *Lomandra longifolia* and *Patersonia glabrata.*

1.4 Grassland on waterlogged soils

The mouths of many of the short, deep coastal gullies have small flats with waterlogged sediments on which a grassland of variable species composition occurs. These areas have been invaded by exotic grasses. Although the structure comprises one stratum, it is variable and heterogeneous, with height ranging from 0.5 to 1.5 m and cover up to 100%. Species present include dominant graminoids such as *Phragmites australis*, *Isolepis nodosus*, *Imperata cylindrica*, **Stenotaphrum secundatum*, *Digitaria didactyla* and *Hemarthria uncinata*, herbs such as *Commelina cyanea*, **Hydrocotyle bonariensis* and *Dichondra repens*, and low growing exotic shrubs such as **Chrysanthemoides monilifera* and **Acacia longifolia* var. *sophorae*. Similar conditions occur on seepage areas below coastal cliffs, where *Gleichenia rupestris* is also abundant. These latter areas are too small or narrow to map separately.

1.5 Woodland/low woodland on ridges, slopes and gullies

The slopes running from the main ridges and plateaux towards the coast generally support a eucalypt woodland. The slopes here are steep, often up to 30°, the aspect varies, but tends towards south-east and there is always some minor exposure to coastal winds and to salt-spray. Where the wind exposure is extreme the structure changes to a low woodland, in which the canopy merges with the shrub layer, but without significant floristic changes. The main tree species, *Eucalyptus umbra*, *E. paniculata*, *Angophora costata* and *Syncarpia glomulifera*, form a layer that varies from a height of 25 m and a cover of 25% to a height of 3 m and 10% cover with increasing exposure. The shrub layer has a variable composition, with common species including *Macrozamia communis*, *Dodonaea triquetra* and *Pultenaea flexilis*. The tall ground cover layer (1.5 m; 30%) is dominated by *Lomandra longifolia*, *Imperata cylindrica*, *Gahnia melanocarpa* and *Pteridium esculentum*. Much variability in the strata

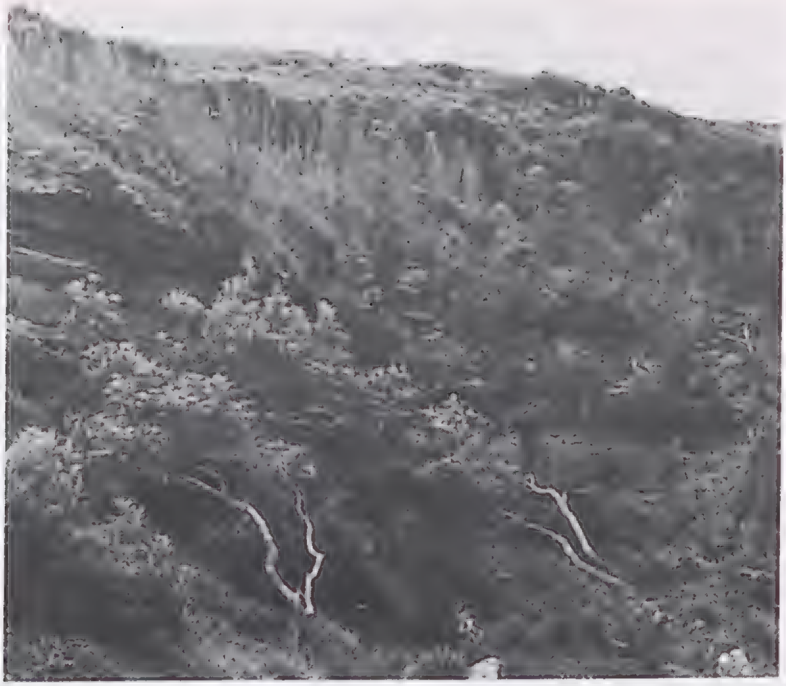

Figure 6. Low woodland, dominated by *Banksia integrifolia* (unit 1.2), on talus above the littoral zone. The talus is derived from the low cliff and from the soils above.

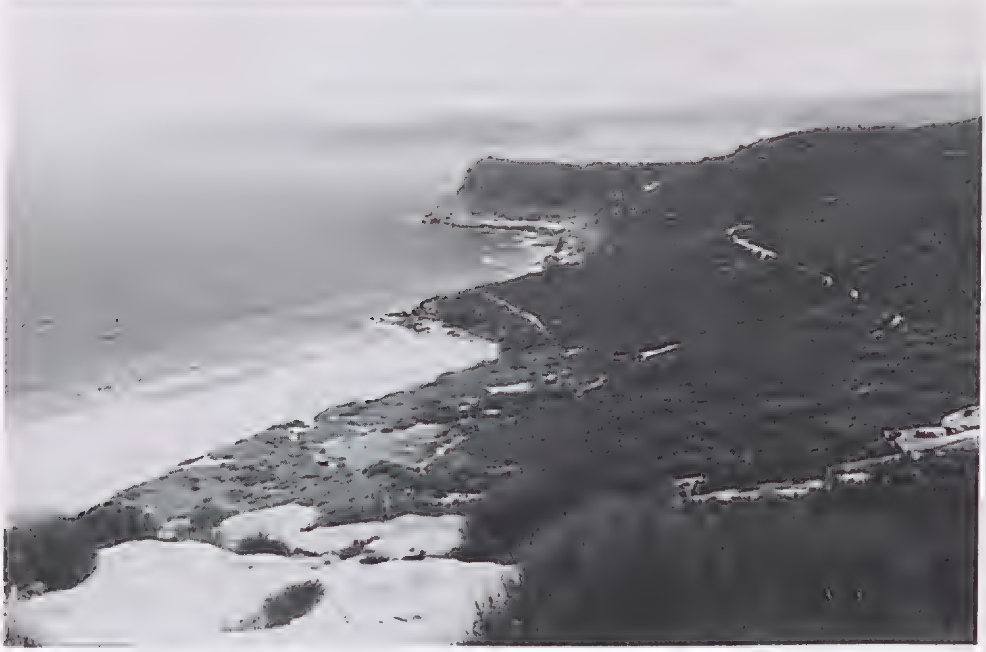

Figure 7. View of coastal heath on Box Head from north of Tallow Beach. The closed-heath on the lower slopes, dominated by *Allocasuarina distyla*, is unit 1.3 and the low shrubland/ open-heath on the ridge-top and upper slopes is unit 2.1.

may be related to aspect and soil, the latter arising from the variable nature of the parent rocks.

The slopes leading down directly to Broken Bay or Brisbane Water, being away from strong coastal influences, support a woodland with different dominant species and a more consistent structure. The tree layer is usually around 20 m high, with 20% cover, and composed of *Eucalyptus maculata*, *Angophora costata*, *Allocasuarina torulosa*, *E. umbra* and *E. gummifera*. The shrub layer (1.2 m; 10%) has a variable florisitic composition. Common species are *Oxylobium ilicifolium*, *Acacia implexa*, *Pultenaea ferruginea*, *P. flexilis*, *Macrozamia communis*, *Hakea sericea* and *Persoonia linearis*, with the local abundance of these varying in a manner that suggests fire history as the cause. The ground cover (0.4 m; 25%) can be fire-affected, with species such as *Lomandra longifolia*, *Entolasia stricta* and *Panicum simile* being displaced by *Imperata cylindrica* after fire.

On the steep slopes north of Mount Bouddi and west of MacMasters Beach is a woodland with a florisitic composition that reflects its drier location, away from the influence of the coast or the bays. Only a small area of this, below the Northwest Ridge, is in the National Park. The tree layer is dominated by *Eucalyptus punctata* and *Allocasuarina torulosa*. As this community occurs mostly between the Park and developed areas the understorey has usually been affected by frequent low-intensity fires. *Imperata cylindrica* is abundant, along with *Pteridium esculentum*, *Culcita dubia* and *Macrozamia communis*.

1.6 Palm-dominated open-forest in incised gullies

On the slopes below Mount Bouddi the gullies are incised, providing a sheltered habitat in which there is an open-forest dominated by palms with an understorey allied to rainforest (Figure 8). The tree layer, growing to 30 m and reaching 60% cover, is composed mainly of *Archontophoenix cunninghamiana* with scattered *Eucalyptus deanei* and *Allocasuarina torulosa*. The small tree layer (10 m; 10%) includes *Livistona australis*, *Duboisia myoporoides*, *Glochidion ferdinandi* and *Acmena smithii*. The understorey is quite open (2 m; 20%), with scattered shrubs, tall graminoids and ground ferns. Shrub species include *Ficus coronata*, *Pittosporum undulatum*, *Notelaea venosa*, *Wilkiea huegeliana*, *Schizomeria ovata*, *Eupomatia laurina* and *Citriobatus pauciflorus*. Ground cover species include *Cissus antarctica*, *Rubus moorei*, *Morinda jasminoides*, *Gymnostachys anceps*, *Dioscorea transversa* and ferns such as *Lastreopsis decomposita*, *Doodia aspera* and *Blechnum cartilagineum*. *Todea barbara* and *Blechnum camfieldii* occur on the banks of the watercourses. **Lantana camara* is abundant in the surrounding eucalypt woodlands, and with time could increase from its currently isolated pockets.

Group 2: Open-heath/woodland on Hawkesbury Sandstone

The Hawkesbury Sandstone plateaus and ridge-tops support characteristic open-heaths and woodlands. These are a small, coastal sub-set of the Hawkesbury Series' sandstone vegetation. There are two main trends within this group: soils with a clay B-horizon and somewhat impeded drainage support such structural types as open-heath, closed-heath, low shrubland and tall shrubland; and other soils support woodland (most commonly), open-woodland and open-forest.

2.1 Low shrubland/open-heath on coastal plateaus

On the Box Head plateau in areas of strong coastal influence, an open-heath or low-shrubland occurs (Figure 7). The main species in the open shrub layer, which varies from 0.3 m to 0.8 m in height and which has typically 15% cover but may reach 30%, are *Allocasuarina distyla, Banksia oblongifolia, B. ericifolia, Dillwynia retorta, Persoonia lanceolata, Hakea teretifolia, Petrophile pulchella, Platysace linearifolia* and *Epacris pulchella*. The ground cover stratum (0.2 m; 20%) includes species such as *Xanthorrhoea media, Patersonia sericea, Cyathochaeta diandra, Lepidosperma viscidum* and *Ptilanthelium deustum*.

2.2 Woodland/open-heath on laterized soils

The 'laterized' soils on Wards Hill support a woodland whose extent has been severely affected by clearing for orchards or by degradation by too frequent burning. It is only poorly represented in the National Park. The tree stratum reaches 12 m and has around 15% cover. Common trees include *Syncarpia glomulifera, Eucalyptus piperita, E. gummifera* and *E. agglomerata*. Common species in the shrub layer (1.2 m; 40%) are *Persoonia levis, Cassinia* sp., *Xylomelum pyriforme, Lambertia formosa* and *Acacia ulicifolia*, while those common in the ground cover (0.5 m; 60%) include *Themeda australis, Xanthorrhoea media* and *Pteridium esculentum*.

Where streams cross the 'laterite' they are flanked by poorly drained areas in which an open-heath develops. There are scattered small trees up to 3 m tall and less than 10% cover, comprising mainly *Angophora costata, Eucalyptus piperita, E. umbra* and *E. pellita*. Under these is a diffuse stratum of shrubs and ground cover species (1 m; 60%). The main shrubs are *Lambertia formosa, Pultenaea elliptica, Banksia oblongifolia, Mirbelia rubiifolia, Acacia ulicifolia* and *Petrophile pulchella*, and the main ground cover species is *Lepidosperma laterale*, but with *Schoenus brevifolius, Xyris operculata* and *Ptilanthelium deustum* important above rock outcrops and other locally wetter areas.

2.3 Woodland/open-heath on plateau soils

On the plateaus where there is not a markedly clayey sub-soil there is a woodland of variable structure. The tree stratum, ranging in height from 8 m to 24 m with around 15% cover, contains species such as *Eucalyptus gummifera, E. piperita, E. pellita, E. paniculata, Angophora costata* and *Allocasuarina torulosa*. Sometimes there is a small tree stratum under this (4 m to 8 m; 20%) of *Banksia serrata, A. torulosa* and *Leptospermum flavescens*. The understorey contains a diverse shrub layer (0.5 m to 2.0 m; 20%) including *Pultenaea flexilis, Acacia ulicifolia, Platysace lanceolata, Dillwynia floribunda, Macrozamia communis* and *Pteridium esculentum* and a ground cover (0.6 m; 10%) dominated by *Themeda australis, Xanthorrhoea media* and *Entolasia stricta*.

On areas where there is a slight impedence of drainage (due to the presence of a clay sub-soil combined with a general concavity of the plateau surface) an open-heath is present, with scattered stands of low woodland. These areas are mainly on the broad 'shoulders' of the plateaus. The tree species *Eucalyptus gummifera, Angophora costata, E. piperita, E. pellita, E.agglomerata, Syncarpia glomulifera* and *E. haemastoma* form a distinct stratum of 3.0 m height and 30% cover in the low woodland stands, or a diffuse tall shrub component in the open-heath. The shrubs, such as *Lambertia formosa, Banksia serrata, Leptospermum attenuatum, Pultenaea elliptica, B. oblongifolia, Acacia ulicifolia* and *Petrophile pulchella* form a distinct layer (1.2 m; 30%) or merge with the ground cover layer (0.3 m; 30%) which contains species such as *Lepidosperma elatius, Schoenus brevifolius, Xyris operculata* and *Ptilanthelium deustum.*

2.4 Woodland on colluvial soil

Where the sandstones are thin and broken-up, allowing the accumulation of humus-rich colluvial soil (which sometimes occurs downslope, over parent rocks of the Narrabeen Series), a woodland dominated by *Eucalyptus pilularis* and *Angophora costata* is present (Figure 9). Other species in the tree stratum (ranging in height from 15 m to 22 m and with 25% cover) include *E. gummifera, E. umbra, E. paniculata* and *Allocasuarina torulosa.* At moister sites there is a tall shrub layer (5 m to 9 m; 15%) with *Acacia irrorata, Glochidion ferdinandi, Leptospermum flavescens, Acacia maidenii, Banksia integrifolia* and *Elaeocarpus reticulatus.* The understorey is composed of a very sparse shrub layer (1.2 m; 2%) and a ground cover layer (0.5 m; 50%) into which the shrub layer frequently merges. Common species are *Macrozamia communis, Pteridium esculentum, Lomandra longifolia, Xanthorrhoea arborea* and *Culcita dubia.*

Group 3: Open-heath/low open-woodland on Pleistocene Alluvium

The vegetation on the perched Pleistocene sand-dunes, the Bombi and Mourawaring Moors, is a distinctive feature of the Peninsula. The podsolized sands support an open-heath or low open-woodland. Structurally these communities are very simple, with a shrub stratum, usually up to 1.5 m high and with 20% cover, often merging with a ground cover stratum, with 80% cover and dominated by graminoids.

3.1 Open-heath on coastal podsols

Where the leached A-horizon is intact there is a distinctive open-heath (Figure 10). The dominant shrub is *Banksia aemula,* with common species including *Allocasuarina distyla, Lambertia formosa, Platysace linearifolia, Isopogon anemonifolius, Persoonia lanceolata* and *Leptospermum flavescens,* mixed with low-growing *Eucalyptus umbra* and *Angophora costata.* Common understorey species include *Hypolaena fastigiata, Bossiaea ensata, Woollsia pungens* and *Lepidosperma* spp.

Where there has not been a recent fire a tall shrubland structure (1 m to 3 m; 15% cover) may develop, with species such as *Allocasuarina distyla, Eucalyptus umbra, Platysace lanceolata, Leptospermum flavescens* and *Styphelia laeta.*

3.2 Low open-woodland on coastal podsols

On the edges of the dunes where the indurated sands are exposed or covered with a thin layer of colluvial leached sand, a low open-woodland develops. Such sites are normally sheltered from any strong coastal influence by their aspect (which ranges from the west to the north), but are on nutrient-poor soils with little nutrient input from salt spray. The tree layer is low, of 3 m to 8 m height and 10% to 50% cover, dominated by *Angophora costata, Eucalyptus umbra* and *Allocasuarina distyla.* The shrub layer (1.2 m; 70%) is dominated by *Banksia aemula, B. serrata, Syncarpia glomulifera, Xanthorrhoea arborea* and *Podocarpus spinulosus.*

3.3 Woodland on inland podsols

Where the main sand-dunes are not affected by coastal exposure there was

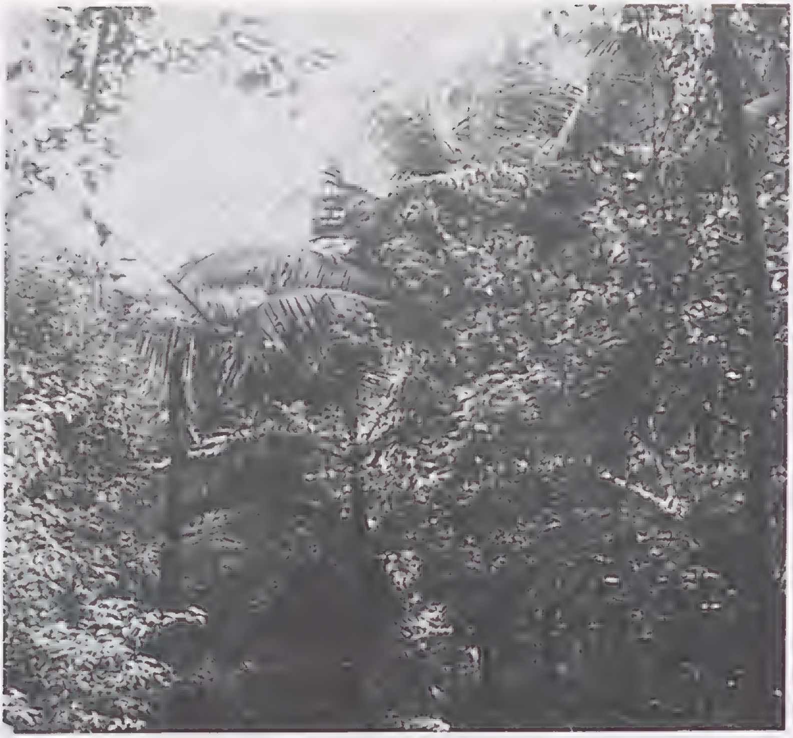

Figure 8. Open-forest, dominated by *Archontophoenix cunninghamiana*, in a sheltered gully 1 km west of Little Beach (unit 1.6).

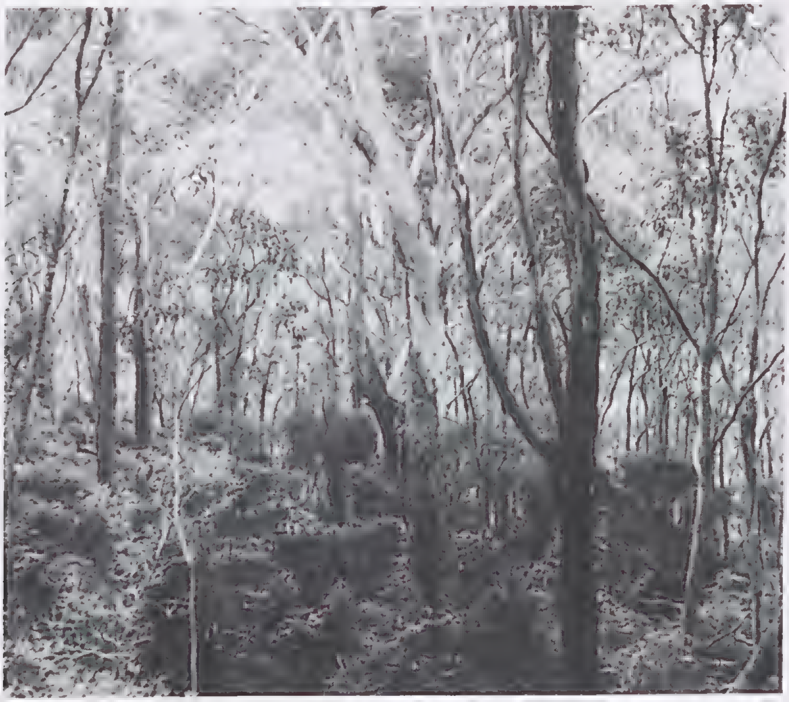

Figure 9. Woodland, dominated by *Eucalyptus pilularis*, on colluvial soil behind Little Beach (unit 2.4).

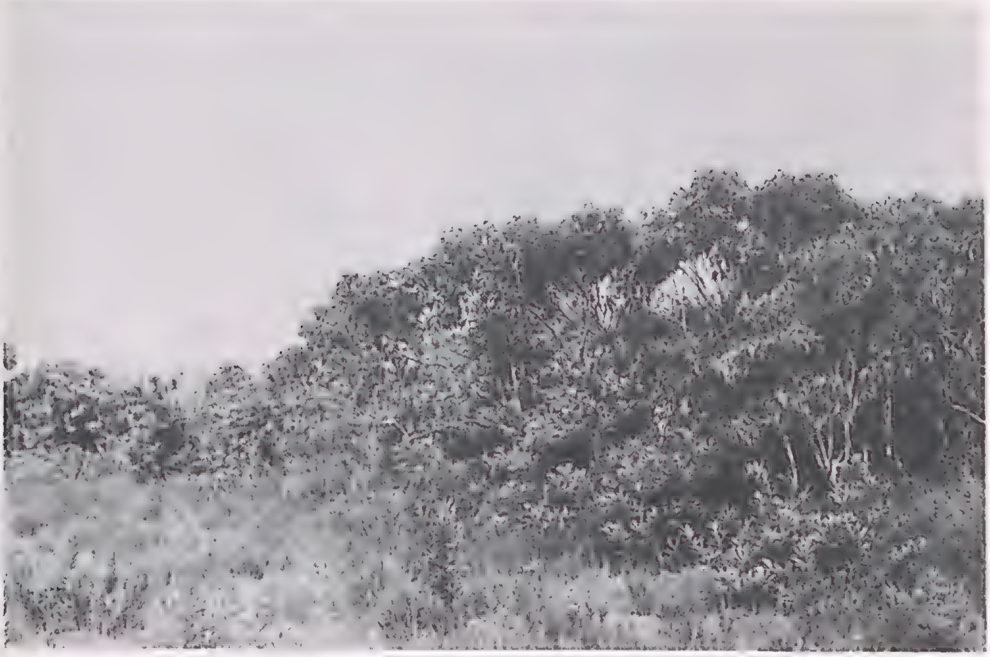

Figure 10. Open-heath on perched sand dune, dominated by *Banksia aemula*, on Bombi Moors (unit 3.1). The low trees are *Eucalyptus umbra* and the main ground cover species is *Hypolaena fastigiata.*

formerly a woodland dominated by *Eucalyptus pilularis* and *Angophora costata.* All of this has been cleared for urban development or for sand extraction, leaving only remnant trees. It appears to have had affinities with the vegetation in the gully south of MacMasters Beach (map unit 2.4).

Group 4: Tall shrubland/woodland on Recent Alluvium.

4.1 Tall shrubland on coastal sand deposits

The beaches on the Peninsula are from 100 m to 1.2 km long and from 20 m to 100 m wide, with the larger beaches backed by simple sand-dune systems. The vegetation on these has been cleared in the past for mineral sand extraction, while the few remaining untouched sections, at the eastern end of Putty Beach, suffer from heavy recreational use. Remnants of the original vegetation include a tall shrub stratum, ranging from 2 m to 8 m in height and with 40% cover, dominated by *Leptospermum laevigatum* and with other shrubs such as *Banksia integrifolia*, *L. attenuatum* and *Macrozamia communis.* The weeds **Lantana camara* and **Chrysanthemoides monilifera* subsp. *monilifera* show fluctuations in local abundance with implementation of various weed control measures. Immediately behind the beaches, in areas disturbed by storm waves, are typical coastal colonizing species such as *Spinifex sericeus*, **Cakile edentula*, *Tetragona tetragonioides* and **Hydrocotyle bonariensis.*

4.2 Woodland on estuarine alluvium

The inlets of Broken Bay and Brisbane Water are fringed by infilled mud-basins, which support a distinctive range of vegetation types. These range from an estuarine complex on saline soils to a moist eucalypt woodland in the enclosed valleys. The latter occurs below Northwest Ridge. Typically the canopy is up to 25 m in height and has 60% foliage cover, and includes species such as *Eucalyptus amplifolia*, *E. deanei*, *E. pilularis*, *E. robusta*, *Angophora floribunda*, *Allocasuarina torulosa* and *Casuarina glauca*. The understorey has generally been modified or cleared for grazing, as has the canopy in many areas. Based on the remnants of the understorey, it may be assumed that tall shrubs were formerly common, especially *Melaleuca styphelioides*, and that there was a dense and diverse ground cover.

Weed Invasion

Reconnaissance indicated that the extent of weed invasion is generally minimal, but also that there were several specific problems that could be related to specific non-natural disturbances. Weed invasion into the periphery of bushland from disturbed ground was generally minor in extent and severity, but was occasionally locally severe around urban areas and along roadways. The detailed study of peripheral weed ingress was conducted at such a site east of Killcare Heights (Figure 1) downslope of a well tended lawn and subject to the deposition of garden clippings and fertiliser. The data are summarised in Figure 11.

The beaches that were mined for mineral sands have major infestations of **Chrysanthemoides monilifera* subsp. *monilifera*. While it is not clear whether or not the local populations arose from plantings as an aid to rehabilitation, they are well established now. Seedlings are often seen in adjacent bushland, apparently due to dispersal of seed by birds. **Lantana camara* was seen to be the most serious problem for the vegetation of the Peninsula. Many hectares of understorey are dominated by dense stands of this bush. The approximate present extent, based on field reconnaissance, is shown in Figure 12. Seed dispersal by birds is probably the primary means of invasion. A number of minor areas of disturbance were found close to the coast. Here species with wind-blown seeds, such as **Gomphocarpus fruticosus* and **Sonchus oleraceus* were occasionally present.

There were 46 exotic species found during the study, and these are listed in Table 2. These species were mainly from the families Poaceae, Asteraceae, Fabaceae and Verbenaceae. Species present only in largely disturbed lands (including lawns, gardens and agricultural lands) were not considered, but some might with time spread into undisturbed lands.

Of the species found, 17 were considered able to invade natural bushland (shown by 'I' after the species' names in Table 2). The other species occurred only on sites that have experienced some form of disturbance, either clearance, too frequent burning or nutrient enrichment. It was possible to assign the species to frequency classes as an index of their general impact on bushland (also shown in Table 2). Seven species had been planted or deposited with garden clippings (shown by '0'). Of the remaining 39 species, 28 are present in bushland only as scattered occurrences, mainly of low local frequency (shown by '1'). Seven species are found more widely, usually in specific habitats and with low or moderate local frequency (shown by '2'). Four species are present with high local frequency (shown by '3'): **C. monilifera*, **G. fruticosus*, **Hydrocotyle bonariensis* and **L. camara*.

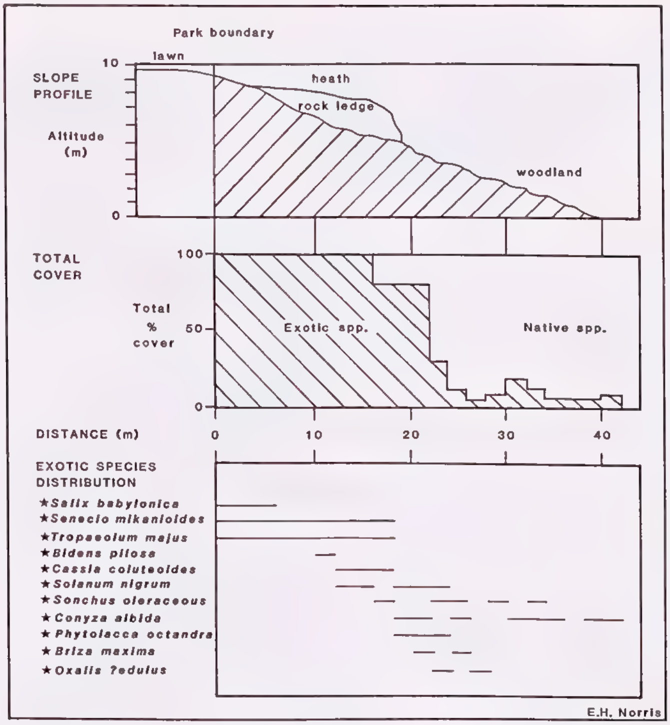

Figure 11. Weeds recorded along a transect at Killcare Heights fall into two groups that could progress further into bushland with time. The first group of three species occurs in areas with high nutrient in-wash, in which native species have been displaced. The second group, which apparently precedes the first, co-exists with native species.

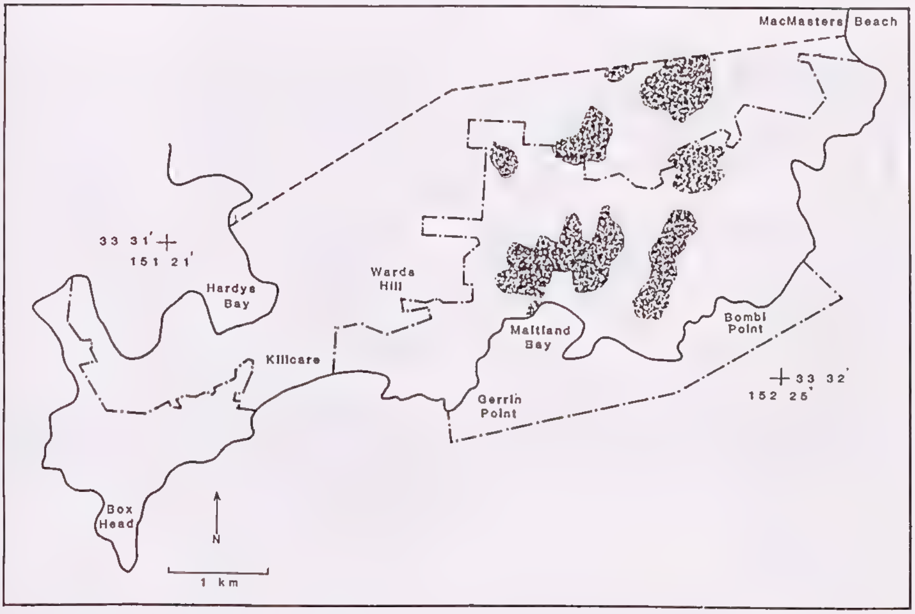

Figure 12. The approximate distribution of **Lantana camara* in the study area.

Table 2. Exotic species in Bouddi National Park.

Species capable of invading bushland are indicated by an (I). A frequency score of '0' (planted or from garden cuttings), '1' (scattered occurrences), '2' (low-moderate frequency, and '3' (high local frequency) is listed for every species.

	Invasiveness	Frequency
PTERIDOPHYTES		
ASPIDIACEAE		
**Cyrtomium falcatum*		1
ANGIOSPERMS		
MONOCOTYLEDONS		
COMMELINACEAE		
**Tradescantia albiflora*	I	1
IRIDACEAE		
**Crocosmia* X *crocosmiiflora*		2
LILIACEAE		
**Protasparagus aethiopicus*	I	1
POACEAE		
**Andropogon virginicus*	I	2
**Briza maxima*		1
**B. minor*		1
**Chloris gayana*		1
**Cortaderia selloana*		2
**Cynodon dactylon*	I	1
**Lagurus ovata*		1
**Paspalum dilatatum*		1
**P. urvillei*	0	
**Stenotaphrum secundatum*		1
DICOTYLEDONS		
APIACEAE		
**Hydrocotyle bonariensis*	I	3
ASCLEPIADACEAE		
**Gomphocarpus fruticosus*	I	3
ASTERACEAE		
**Ageratina adenophora*	I	1
**Bidens pilosa*		1
**Chrysanthemoides monilifera*	I	3
**Chrysanthemum maximum*		0
**Conyza albida*	I	2
**Coreopsis lanceolata*		1
**Hypochoeris radicata*		1
**Senecio mikanioides*		1
**Sonchus oleraceus*	I	1
BRASSICACEAE		
**Cakile edentula*		1
CACTACEAE		
**Opuntia stricta*		0
CONVOLVULACEAE		
**Ipomoea indica*		1
CRASSULACEAE		
**Kalanchoe tubiflora*		1
FABACEAE — CAESALPINIOIDEAE		
**Cassia coluteoides*		1
FABOIDEAE		
**Erythrina* X *sykesii*	1	
**Trifolium* sp.		0
MIMOSOIDEAE		
Acacia longifolia var. *sophorae*		2
LAURACEAE		
**Cinnamomum camphora*	I	1
MALVACEAE		
**Sida rhombifolia*	I	2
OLEACEAE		
**Ligustrum lucidum*	I	1
**L. sinense*	I	2
OXALIDACEAE		
**Oxalis ?edulis*		1
PASSIFLORACEAE		
**Passiflora edulis*		1
PHYTOLACCACEAE		
**Phytolacca octandra*	I	1
SALICACEAE		
**Salix babylonica*		0
SOLANACEAE		
**Solanum nigrum*	I	1
THUNBERGIACEAE		
**Thunbergia alata*		1
TROPAEOLACEAE		
**Tropaeolum majus*		0
VERBENACEAE		
**Lantana camara*	I	3
**Verbena bonariensis*		0

Rare or restricted species

Records for the Peninsula include one rare species and one vulnerable species (as defined by Leigh et al., 1981), but no restricted or endangered species. However, in the future, other species may be recorded or current species may change in status, due to changes in fire regime, pressure from exotic species or further land clearance.

Blechnum ambiguum[2] (Blechnaceae) is a ground fern found around the edges of the Hawkesbury Sandstone. It is considered to be vulnerable and at a long-term risk (classed as '3V' by Leigh et al.). It was listed for the Park in the National Parks and Wildlife Service plant list (1978), and was not found during the current survey.

Rulingia hermaniifolia (Sterculiaceae) is a shrub found on coastal headlands from Kurnell to Broken Bay and also inland from Jervis Bay along the Shoalhaven River. It is considered to be rare and to be adequately conserved, because, although it occurs in small populations, it is protected within national parks. It was recorded within Bouddi National Park by Siddiqi (1971), by D. Lambert (pers. comm.) and was found in the present survey at two locations: two plants and about 15 seedlings were found on a small ledge on top of a cliff at Caves Bay, and a group of small plants were found in heath, burnt three years previously, on the eastern edge of the Bombi Moors. Field observations suggest this low spreading shrub may be fire sensitive. It flowers in October and old seed pods have been seen on (presumably) three-year-old plants.

Discussion

Vegetation

Bouddi National Park is the only conservation reserve in the study area. Its efficacy in conserving the vegetation of the Peninsula can be estimated from the areas, in both absolute and relative terms, that the plant communities and groups occupy in the Park (given in Table 3). It is useful to consider these values on local, district, region and State scales.

On the local scale, some communities on the Peninsula are not well represented in the Park. Unit 2.2 (woodland/ open-heath on 'laterized' soils) is poorly represented, and the area that is in the Park shows little of its overall diversity. Both map units in group 4 (Tall shrubland/ woodland on recent alluvium) are represented by very small areas that have been largely disturbed.

On the district scale, the range of vegetation in Bouddi National Park has marked differences with that of nearby conservation reserves, as shown in Table 4 (Benson & Fallding 1981 and Benson 1980 and general reconnaissance). Only group 2 is well represented in these reserves.

The pattern on the regional scale is like that on the local scale: vegetation types represented by map units 2.2, 4.1 and 4.2 have generally been cleared or disturbed throughout their extent in the Central Coast. Unit 1.6 (palm-dominated open-forest) is on the edge of a gap in the distribution of the diverse warm-temperate rainforests of the coastal ranges, with which it is allied (on the basis of general species composition, not dominant species). Warm-temperate rainforest occurs to the west in the most sheltered or enriched sites in the Blue Mountains, but with a generally depauperate species composition, and rarely including *Archontophoenix cunninghamiana.* Further, the species composition changes with latitude (Baur 1957), with most of the dominant species occurring no further south than Batemans Bay. Reserves in the region with this rainforest include Barrington Tops National Park and some Flora Reserves in the State Forests of the Watagan Ranges (to the north); Wollemi National Park, and Blue Mountains National Park (to the west) and Royal National Park (to the south) (Figure 1).

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[2] A revision of Leigh et al., which was published after this work was completed, omits *B. ambiguum* but includes *R. hermaniifolia* with the same status. [Briggs, J.D. & Leigh, J.H. (1988), *Rare or threatened Australian Plants*. Special Publication 14, Australian National Parks and Wildlife Service, Canberra.]

On the State-wide scale, Bouddi National Park is an important part of the State's system of conservation reserves in that it is one of only five in the coastal portion of the Central Coast and is also part of an important series of reserves in the valley of the Hawkesbury River, covering almost the full range of habitats present from the coast to the Great Divide.

Table 3. Areas of plant communities and groups of map units in Bouddi National Park.

Map units	Area (ha)	% Area of unit	% Area of Park
1	456		54
1.1	24	5	3
1.2	4	1	~0
1.3	65	14	8
1.4	6	1	~0
1.5	332	73	39
1.6	25	5	3
2	261		31
2.1	68	26	8
2.2	5	2	1
2.3	46	18	6
2.4	142	54	17
3	110		14
3.1	100	91	13
3.2	10	9	1
4	3		~0
4.1	3	100	~0
4.2	~0	~0	~0

Notes: * "~0" signifies that the value is less than 0.5.

* The total area covered by the vegetation is 830 ha. There are also 41 ha in the Park that are cleared, disturbed or naturally without vegetation (e.g. rock ledges). A further 290 ha of the Park are in a marine extension.

Fire

The frequency of fires may strongly influence the effectiveness of any plant reproduction strategy. Seed-based strategies require an interval between fires long enough to allow sufficient seed set. Too-frequent fires can deplete the

Table 4. Conservation status of the four map unit groups in Bouddi National Park compared with three adjacent reserves.

Map Unit Group	Bouddi National Park	Brisbane Water Park	Ku-ring-gai Natnl.Chase Park	Muogamarra Natnl.Nature Group
1	+	~	~	—
2	+	+	+	+
3	+	—	—	—
4	~	—	—	—

Key: + well conserved, ~ minor representation, — not conserved.

nutrient reserves in lignotubers, limit the number of epicormic buds available, deplete seed reserves or leave a plant with insufficient nutrients to resprout. This often leads to selection of plants not so affected which have been uncommon under other fire regimes. The time of year in which a fire occurs may affect the rates of germination of seeds, and so may determine the dominant species in the initial stages of recovery. Two significant fire effects were observed.

Firstly, where repeated burns aimed at fuel reduction occur around the urban edges *Imperata cylindrica* and *Pteridium esculentum* have become locally dominant. While this may not be a desirable event in the National Park it is an acceptable consequence of the steps necessary to protect life and property from fire elsewhere on the Peninsula. Secondly, it appears that fire interacting with an extreme environmental factor can affect the distribution and structure of the vegetation, specifically at the boundary of the areas exposed to coastal winds and saltspray. The mapped boundaries between units 1.3 (closed or open-heath) and 1.5 (woodland/low woodland) probably reflect past fire patterns. In such cases there appears to be a balance between two opposing processes. Firstly fires push the woodland edge away from the coast by allowing die-back due to salt spray where previously sheltering foliage is burnt. Secondly the woodland species can re-establish themselves where the coastal heath (1.3) that replaces them provides shelter from exposure to salt spray. This process must be considered during the planning of fuel reduction burns, to avoid unwanted changes in areas of high recreational or aesthetic amenity.

Weed Invasion

The level of weed ingress from the edges of cleared or disturbed land is presently limited due mainly to the relatively recent spread of urban development, with newer developments tending to be placed on the periphery of older developments. Also the prescribed burns around the edge of developed areas, aimed at reducing wildfire hazard, have not often stressed the native vegetation to a level that would facilitate weed spread.

With time the urban areas will become more established, with lawns and gardens maturing and diversifying and providing more sources of weed species. Existing areas of weed ingress will, in the absence of active management, consolidate. Further, there will be increased pressure on managers of bushland to provide more frequent fuel reduction burns, which will further stress native vegetation.

The areas of disturbed beach sand currently supporting stands of

**Chrysanthemoides monilifera* are subjected, at erratic intervals, to rehabilitation measures ranging from hand extraction in the National Park to bulldozing elsewhere. As a result the state of these problems in the future is unpredictable. The spread of seeds into surrounding woodlands results in scattered and sometimes dense seedling establishment. While such occurences are reported occasionally throughout the coastal parts of the Sydney Basin, there is little indication that mature plants are likely to result.

The stands of **Lantana camara* in relatively undisturbed bushland will be extremely difficult to control. The combination of limited access and the need to avoid disturbing the native species rule out most control measures. There is some potential for biological control (as discussed by Hadlington 1968). The outlook for the future is thus that active management will be required to restrict weed invasion.

Rare or restricted species

The conservation of the rare or restricted species in an area such as the Peninsula is possible as long as the species' requirements are taken into account when planning management operations such as prescription burning and as long as their distributions are made known to those who plan operations that lead to disturbance or clearing of bushland. This should be possible in and around Bouddi National Park.

Acknowledgements

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Appendix

Floristic list for Bouddi Peninsula

There were 359 species from 94 families recorded during this survey. An additional 69 species were recorded from the area by other sources (Siddiqi 1971; National Parks and Wildlife Service 1978; Jelinek 1979). The floristic list is arranged heirarchically: alphabetically for species, genera and families and systematically for higher groups. All names used are as in Jacobs & Pickard (1981) except for those where the National Herbarium of New South Wales has since adopted another name.

In the list the taxa are given first, with species italicised and higher groups in upper case. Exotic species are prefixed with an asterix (*). After this, for those species recorded during this survey, is a code for the main growth habit observed. The numbers after these are the map unit groups in which the species was observed, or if prefixed with a question mark (?), the groups in which it is reported to occur. Where a hash symbol (#) is given, the species was not found in natural vegetation in the study area.

The map unit groups are:

1 Coastal grassland/heath/woodland on Narrabeen Series.
2 Open-heath/woodland on Hawkesbury Sandstone.
3 Open-heath/low open-woodland on Pleistocene alluvium.
4 Tall shrubland/woodland on Recent alluvium.

The life-form abbreviations are:

T: tree, ST: small tree, TS: tall shrub, S: shrub, SS: small shrub, CY: cycad, TG: tall graminoid, G: graminoid, SE: seedling only, GF: ground fern, RF: rock fern, RO: rock orchid, EP: epiphyte, V: vine, TH: tall herb, H: herb.

PTERIDOPHYTES
ADIANTACEAE
Adiantum aethiopicum (GF) 1 2
A. *hispidulum* (GF) 1
Cheilanthes sieberi (GF) 2
ASPIDIACEAE
**Cyrtomium falcatum* (RF) 1
Lastreopsis decomposita (GF) 1
Polystichum australiense (GF) 1
ASPLENIACEAE
Asplenium flabellifolium (GF) 1
BLECHNACEAE
Blechnum camfieldii (GF) 1
B. cartilagineum (GF) 1 2
Doodia aspera (GF) 1 2
CYATHEACEAE
Calochlaena dubia (GF) 1 2
DAVALLIACEAE
Davallia pyxidata (RF) 2
DENNSTAEDTIACEAE
Pteridium esculentum (GF) 1 2 3
GLEICHENIACEAE
Gleichenia dicarpa (GF) 2
G. *rupestris* (GF) 1
LINDSAEACEAE
Lindsaea linearis (GF) 1 2
OSMUNDACEAE
Todea barbara (GF) 1
POLYPODIACEAE
Platycerium bifurcatum (RF) 2
SELAGINELLACEAE
Selaginella uliginosa (SS) 2
THELYPTERIDACEAE
Christella dentata (GF) 1
GYMNOSPERMS
PODOCARPACEAE
Podocarpus spinulosus (S) 2 3
ZAMIACEAE
Macrozamia communis (CY) 1 2 3

ANGIOSPERMS
MONOCOTYLEDONS
ARACEAE
Gymnostachys anceps (TG) 1 2
ARECACEAE
Archontophoenix cunninghamiana (T) 1
Livistona australis (T) 1
COMMELINACEAE
Commelina cyanea (H) 1
**Tradescantia albiflora* (H) #
CYPERACEAE
Carex appressa (G) 1
Caustis flexuosa (G) 2
C. *pentandra* (G) 2
Cyathochaeta diandra (G) 1 2
Eleocharis sp. (G) 2
Gahnia clarkei (TG) 2
G. *melanocarpa* (TG) 1
Isolepis nodosus (G) 1
Lepidosperma elatius (TG) 2
L. laterale (G) 1 2
L. squamatum (G) 1
L. viscidum (G) 1 2
Ptilanthelium deustum (G) 2
Schoenus brevifolius (G) 2 3

S. ericetorum (G) 3
S. melanostachys (G) 1 2
DIOSCOREACEAE
Dioscorea transversa (V) 1 2
HAEMODORACEAE
Haemodorum planifolium (G) 2 3
IRIDACEAE
*_Crocosmia_ X _crocosmiiflora_ (G) #
Libertia paniculata ?1
Patersonia glabrata (G) 1 2 3
P. sericea ?2
JUNCACEAE
Juncus antarcticus (G) 1
*_J. cognatus_ (G) 2
J. continuus ?1
J. kraussii (G) 1
J. planifolius (G) 1
JUNCAGINACEAE
Triglochin striata (G) 1
LILIACEAE
Blandfordia sp. (G) 1
Caesia sp. (G) 1
Dianella caerulea (G) 1 2
*_Protasparagus aethiopicus_ cv. 'sprengeri' (V) #
Schelhammera undulata (H) 2
Sowerbaea juncea ?3
Stypandra glauca (G) 1
Thelionema umbellatum ?3
Thysanotus juncifolius (G) 2
ORCHIDACEAE
Calaena major ?3
Cryptostylis erecta (G) 2
Cymbidium suave (EP) 2
Dendrobium linguiforme (RO) 2
D. speciosum (RO) 2
Dipodium punctatum (G) 2
Diurus aurea ?3
Liparis reflexa (RO) 2
PHILESIACEAE
Eustrephus latifolius (V) 1 2
Geitonoplesium cymosum (V) 1
POACEAE
*_Ammophila arenaria_ (G) ?4
*_Andropogon virginicus_ (G) #
Anisopogon avenaceus (G) 1 2 3
Aristida sp. (G) 1
*_Briza maxima_ (G) #
*_B. minor_ (G) #
Chionochloa pallida (G) 1
*_Chloris gayana_ (G) #
*_Cortaderia selloana_ (TG) 2
*_Cynodon dactylon_ (G) #
Danthonia pilosa (G) 2
Deyeuxia quadriseta (G) 1
Digitaria didactyla (G) 1
D. parviflora (G) 1
Echinopogon caespitosus (G) 1
Entolasia marginata (G) 2
E. stricta (G) 1 2
Eragrostis brownii (G) 1
Festuca littoralis (G) 1
Hemarthria uncinata (G) 1
Imperata cylindrica (G) 1 2
*_Lagurus ovatus_ (G) #
Oplismenus imbecillis (G) 1 2
Panicum simile (G) 2
Paspalidium radiatum (G) 1
*_Paspalum dilatatum_ (G) #
*_P. urvillei_ ?3
Phragmites australis (TG) 1
Poa affinis (G) 1
P. poiformis (G) 1
Spinifex sericeus (G) 4
*_Stenotaphrum secundatum_ (G) 1
Stipa rudis (G) 1
Themeda australis (G) 1 2
RESTIONACEAE
Hypolaena fastigiata (G) 1 2 3 4
Lepyrodia scariosa ssp._meiostachyus_ (G) 2
Restio tetraphyllus (G) 2
SMILACACEAE
Smilax australis (V) 1 2
S. glyciphylla (V) 1 2 4
Ripogonum fawcettianum (V) 1
XANTHORRHOEACEAE
Lomandra glauca (G) 1 3
L. confertifolia ssp._rubiginosa_ ?2
L. filiformis ?2
L. longifolia (G) 1 2 3 4
L. micrantha ?1
L. multiflora (G) 1 2
L. obliqua (G) 1 2
Xanthorrhoea arborea (TG) 2 3
X. macronema (TG) 1
X. media (TG) 1 2
XYRIDACEAE
Xyris gracilis (G) 2
X. operculata ?3

DICOTYLEDONS
ACANTHACEAE
Pseuderanthemum variabile (H) 2
AIZOACEAE
Carpobrotus glaucescens (H) 1
Tetragonia tetragonioides (H) 4
APIACEAE
Actinotus helianthi (H) 1 2 3 4
A. minor (H) 1
Apium prostratum (H) 1
Centella asiatica (H) 1
*_Hydrocotyle bonariensis_ (H) 1
Platysace lanceolata (S) 3
P. linearifolia (S) 2 3
Xanthosia pilosa (H) 1 2 3
X. tridentata (H) 1 2

APOCYNACEAE
Parsonsia straminea (V) 1 2
ARALIACEAE
Astrotricha latifolia (S) 1
Polyscias sambucifolia (TH) 1
ASCLEPIADACEAE
**Gomphocarpus fruticosus* (TH) 1
Marsdenia suaveolens ?1 ?3
ASTERACEAE
**Ageratina adenophora* (TH) 1
**Bidens pilosa* (H) #
Cassinia aureonitens (S) 1
C. longifolia ?2
C. uncata (S) 1 2
**Chrysanthemoides monilifera* (S) 1
**Conyza albida* (H) 1
**Coreopsis lanceolata* (H) #
Epaltes australis (H) 1
Helichrysum bracteatum ?2
H. diosmifolium (S) 2
**Hypochaeris radicata* (H) #
Olearia tomentosa ?1
Senecio bipinnatisectus ?1
S. hispidulus (H) 4
S. lautus ?1
S. linearifolius ?1
**S. mikanioides* (V) #
S. vagus (H) 1
**Sonchus oleraceus* (H) 1
Vernonia cinerea (H) 2
BAUERACEAE
Bauera rubioides ?2
BIGNONIACEAE
Pandorea pandorana (V) 1 2
BRASSICACEAE
**Cakile edentula* (H) 4
CACTACEAE
**Opuntia stricta* ?1
CAMPANULACEAE
Wahlenbergia gracilis ?1
CASUARINACEAE
Allocasuarina distyla (S) 1 2 3 4
A. littoralis (S) 1 2
A. torulosa (S) 1 2
CELASTRACEAE
Maytenus silvestris (S) 1 2 3
CHLOANTHACEAE
Chloanthes stoechadis (S) 1 2
CONVOLVULACEAE
Dichondra repens (H) 1
**Ipomoea indica* (V) #
Polymeria calycina (H) 1
CRASSULACEAE
Crassula sieberiana (H) 1
**Kalanchoe tubiflora* (H) 1
CUNONIACEAE
Ceratopetalum apetalum (T) 1
Schizomeria ovata (T) 1
DILLENIACEAE
Hibbertia aspera (SS) 2
H. bracteata ?1
H. cistiflora ?1
H. dentata (V) 1
H. empetrifolia (SS) 2
H. fasciculata ?1
H. monogyna (SS) 1 2 3 4
H. obtusifolia ?1
H. riparia ?1
H. scandens (V) 1
DROSERACEAE
Drosera auriculata ?2
D. binata ?2 ?3
D. spathulata ?2
EBENACEAE
Diospyros australis (TS) 1 2
ELAEOCARPACEAE
Elaeocarpus reticulatus (TS) 1 2
EPACRIDACEAE
Acrotriche divaricata (S) 2
Astroloma humifusum (S) 3
A. pinifolium (SS) 3
Brachyloma daphnoides (SS) 3
Epacris longiflora (S) 1
E. microphylla (S) 2
E. pulchella (S) 1 2 3
Leucopogon appressus ?1
L. deformis ?1
L. ericoides ?1
L. esquamatus (S) 1 2 3
L. juniperinus ?1
L. lanceolatus (S) 1
L. parvifolium ?1
Monotoca elliptica (S) 2
M. scoparia (S) 1 2 3
Sprengelia incarnata (S) 2
Styphelia laeta (S) 2 3
S. tubiflora (S) 1 3
Trochocarpa laurina (S) 1
Woollsia pungens (SS) 1 2 3
EUPHORBIACEAE
Amperea xiphoclada ?1
Breynia oblongifolia (S) 1 2
Glochidion ferdinandi (TS) 1 2
Micrantheum ericoides (SS) 1 2 3
Omalanthus populifolius (S) 1
Phyllanthus hirtellus (SS) 1 2
Poranthera corymbosa ?3
P. ericifolia ?3
Pseudanthus orientalis ?3
Ricinocarpos pinifolius (S) 1 2 3
EUPOMATIACEAE
Eupomatia laurina (TS) 1
FABACEAE
CAESALPINIOIDEAE
**Cassia coluteoides* (S) 2

FABOIDEAE
Aotus ericoides (S) 3
Bossiaea ensata (SS) 2 3
B. heterophylla (SS) 2 3
B. scolopendria ?3
Daviesia corymbosa ?1
D. ulicifolia (SS) 2
Desmodium brachypodum (V) 1 2
Dillwynia floribunda (S) 1 2
D. glaberrima (S) 1
D. retorta (S) 2
D. sericea (S) 2
**Erythrina* X *sykesii* (ST) #
Glycine tabacina (V) 1 2
Gompholobium grandiflorum ?1
G. latifolium (S) 1 2
G. virgatum ?2
Hardenbergia violacea (V) 1 2
Indigofera australis ?1
Jacksonia scoparia ?3
Kennedia rubicunda (V) 1 2
Mirbelia rubiifolia (SS) 1 2
Oxylobium ilicifolium (S) 1 2
Platylobium formosum (SS) 1 2
Pultenaea daphnoides (S) 2
P. elliptica (S) 1 2
P. ferruginea var. *deanei* (S) 1 2 3
P. flexilis (TS) 1 2
**Trifolium* sp. ?1
MIMOSOIDEAE
Acacia elata ?1
A. filicifolia ?1
A. implexa (TS) 1
A. irrorata (TS) 2
A. longifolia var.*sophorae* (TS) 1
A. maidenii (TS) 2
A. myrtifolia (S) 1 2
A. oxycedrus (S) 2
**A. saligna* (TS) 1
A. suaveolens (S) 1 2 3
A. ulicifolia (S) 1 2 3
FLACOURTIACEAE
Scolopia braunii (S) 1
GERANIACEAE
Pelargonium australe (H) 1
P. inodorum (H) 2
GOODENIACEAE
Dampiera stricta (H) 1 2
Goodenia bellidifolia (H) 1 2
G. heterophylla (H) 2
Scaevola ramosissima (H) 1 2
HALORAGACEAE
Gonocarpus teucrioides (SS) 1 2
LAMIACEAE
Plectranthus parviflorus (H) 2
Prostanthera linearis (S) 2
Westringia fruticosa (S) 1 4
LAURACEAE
Cassytha glabella (V) 1 2 3
**Cinnamomum camphora* (ST) 1
Cryptocarya sp. (S) 1
Endiandra sieberi (ST) 1
LENTIBULARIACEAE
Utricularia laterifolia ?2
LOBELIACEAE
Lobelia alata (H) 1
Pratia purpurascens (H) 1
LOGANIACEAE
Logania albiflora ?1
Mitrasacme polymorpha (H) 2
LORANTHACEAE
Amyema pendulum (EP) 2
Dendrophthoe vitellina (EP) 2
Muellerina eucalyptoides ?3
MALVACEAE
Howittia trilocularis (S) 1
**Sida rhombifolia* (H) 1
MELIACEAE
Synoum glandulosum ?1
MENISPERMACEAE
Sarcopetalum harveyanum (V) 1 2
Stephania japonica var. *discolor* (V) 1
MONIMIACEAE
Wilkiea huegeliana (S) 1
MORACEAE
Ficus coronata (S) 1
F. rubiginosa (ST) 1
Malaisia scandens (V) 1
MYOPORACEAE
Myoporum acuminatum ?1
M. insulare (H) 1
MYRSINACEAE
Aegiceras corniculatum (SE) 1
Rapanea howittiana (S) 1 2
R. variabilis (S) 1 2
MYRTACEAE
Acmena smithii (S) 1
Angophora costata (T) 1 2 3
A. floribunda (T) 1 2
A. hispida (TS) 2
Backhousia myrtifolia ?1
Baeckea brevifolia ?1
B. diosmifolia (S) 1
B. imbricata (S) 1 4
B. ramosissima (S) 2
Callistemon citrinus (TS) 1
C. linearis (TS) 1
Calytrix tetragona (S) 2
Eucalyptus botryoides (T) 1
E. capitellata (ST) 2
E. deanei (T) 1
E. gummifera (T) 1 2
E. haemastoma (ST) 2
E. maculata (T) 1
E. paniculata (T) 1 2

E. pellita (ST) 2
E. pilularis (T) 1 2
E. piperita subsp. *piperita* (T) 2
E. punctata subsp. *punctata* (T) 2
E. robusta (T) 4
E. umbra subsp. *umbra* (T) 1 2 3
Kunzea ambigua (S) 2
Leptospermum attenuatum (TS) 2
L. juniperimun (S) 1
L. laevigatum (TS) 1 4
L. polygalifolium (TS) 1 2 3
L. scoparium ?2
L. squarrosum (S) 1
Melaleuca biconvexa ?4
M. linariifolia ?4
M. styphelioides (TS) 4
M. thymifolia (TS) 1
Micromyrtus ciliata ?2
Rhodamnia rubescens (S) 1
Syncarpia glomulifera (ST) 1 2 3
Syzygium oleosum (S) 1
Tristaniopsis collina (TS) 1
T. laurina (TS) 1
OLEACEAE
**Ligustrum lucidum* (ST) #
**L. sinense* (TS) 1
Notelaea longifolia (TS) 1
N. venosa (S) 1
OXALIDACEAE
**Oxalis ?edulis* (H) #
**O. ?rubens* (H) 1
PASSIFLORACEAE
**Passiflora edulis* (V) 4
PHYTOLACCACEAE
**Phytolacca octandra* (H) #
PITTOSPORACEAE
Billardiera scandens (V) 1 2
Citriobatus pauciflorus (S) 1
Pittosporum revolutum (S) 1 2
P. undulatum (S) 1
PLANTAGINACEAE
Plantago hispida (H) 1
POLYGALACEAE
Comesperma ericinum (S) 2
PROTEACEAE
Banksia aemula (TS) 1 2 3
B. ericifolia (TS) 1 2 4
B. integrifolia (ST) 1 2
B. oblongifolia (S) 1 2 3
B. serrata (TS) 2 3
B. spinulosa var. *collina* (S) 1 2
Conospermum longifolium (S) 2
C. taxifolium (S) 3 4
Grevillea linearifolia (S) 1 2
Hakea dactyloides (S) 2
H. gibbosa (S) 1 2 4
H. sericea (S) 1 2 3
H. teretifolia (S) 1 2
Isopogon anemonifolius (S) 1 2 3 4
I. anethifolius (S) 1 2 3 4
Lambertia formosa (S) 1 2 3
Lomatia silaifolia (S) 2
Persoonia lanceolata (TS) 1 2 3 4
P. levis (TS) 1 2
P. linearis (TS) 1
P. sp. aff. *pinifolia* (S) 2
Petrophile pulchella (S) 1 2
P. sessilis ?3
Telopea speciosissima ?2
Xylomelum pyriforme (TS) 2 3
RANUNCULACEAE
Clematis aristata (V) 1 2
RHAMNACEAE
Pomaderris ?ferruginea (S) 1
P. lanigera (S) 1
ROSACEAE
Rubus hillii (V) 1
R. moorei (V) 1
R. rosifolius (V) 1
RUBIACEAE
**Coprosma repens* ?2
Morinda jasminoides (V) 1
Opercularia aspera (S) 1
Pomax umbellata (H) 1 2
Psychotria loniceroides (S) 1
RUTACEAE
Asterolasia correifolia (S) 1
Correa reflexa (S) 1 4
Crowea saligna (S) 2
Eriostemon australasius (S) 2 3
E. hispidulus (S) 2
Zieria pilosa (S) 1
Z. smithii (S) 1
SALICACEAE
**Salix babylonica* ?2
SANTALACEAE
Exocarpos cupressiformis (TS) 1
SAPINDACEAE
Dodonaea triquetra (S) 1 2 3
Guioa semiglauca ?1
SOLANACEAE
Duboisia myoporoides (S) 1
**Solanum nigrum* (S) #
STERCULIACEAE
Brachychiton populneus (T) 2
Lasiopetalum ferrugineum (S) 1 2 4
L. macrophyllum ?1
Rulingia hermanniifolia (SS) 1
THUNBERGIACEAE
**Thunbergia alata* (H) #
THYMELAEACEAE
Pimelea linifolia (S) 1 2 3 4
Wikstroemia indica (S) 1
TREMANDRACEAE
Tetratheca ericifolia ?3
T. thymifolia (SS) 2

TROPAEOLACEAE
**Tropaeolum majus* ?2
VERBENACEAE
Clerodendrum tomentosum (S) 1
**Lantana camara* (TS) 1 2
**Verbena bonariensis* ?1

VIOLACEAE
Hybanthus monopetalus (H) 1 2
Viola betonicifolia (H) 1
VITACEAE
Cayratia clematidea (V) 2
Cissus antarctica (V) 1
C. hypoglauca (V) 1 2

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Bryophytes of Mount Tomah Botanic Garden

Helen P. Ramsay, Alison Downing and W. B. Schofield

Abstract

Ramsay, Helen[1], Alison Downing[2] & W.B. Schofield[3] ([1]National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000; [2]School of Biological Sciences, Macquarie University, Sydney, Australia 2109; [3]Botany Department, University of British Columbia, Vancouver, B.C. V6G 2B1, Canada) 1990. Bryophytes of Mount Tomah Botanic Garden. Cunninghamia 2(2): 295–303. A total of 85 species, including 63 mosses, 21 liverworts, and one hornwort have been collected in the Mount Tomah Botanic Garden. The species present include those native to a remnant of closed forest and those present in the cultivated garden area at Mount Tomah opened as a cold climate annexe to the Royal Botanic Gardens Sydney in 1987. Several names have been added to the list of species previously known from the Central Tablelands (CT) region of New South Wales.

Introduction

The Mount Tomah Botanic Garden, was developed as an extension of the Royal Botanic Gardens Sydney, for the cultivation and display of cool-climate plants of the world, especially those from the Southern Hemisphere (Rodd 1987a).

Mount Tomah (an Aboriginal word referring to 'tree ferns' (Ingram 1987)), is about 120 km from Sydney and 850 metres above sea level, and is one of several peaks capped with Tertiary basalt in the Blue Mountains north of the Grose River Valley. The basalt cap overlays Triassic shales and sandstones that have been exposed by weathering (Pickett 1987, Branagan & Packham 1967).

The Garden, covering some 31 hectares, contains two valuable pockets of temperate rainforest characterised by Sassafras (*Doryphora sassafras*), Coachwood (*Ceratopetalum apetalum*), and Blackwood (*Acacia melanoxylon*), the tree ferns *Dicksonia* and *Cyathea*, as well as mosses, lichens and epiphytes. The garden is situated in wet sclerophyll forest, dominated by Brown Barrel (*Eucalyptus fastigiata*). Specimens of Southern Beech (*Nothofagus*) including *N. moorei*, one of three *Nothofagus* species present in the garden and *N. procera*, the deciduous Southern Beech from Chile line the garden entrance. The 18 hectares of formal garden, contain cool-climate taxa including *Rhododendrons*, members of the Proteaceae, selected conifers etc.

A large rock garden has been created from local basalt, and includes a cascade and ponds as well as a scree slope and *Sphagnum* bog. Limestone has been imported from Portland, west of the Blue Mountains, to feature calcium-loving plants from around the world. Mature trees and shrubs, present on the site prior to its development as a Botanic Garden, have been retained. These include traditionally cultivated Northern Hemisphere temperate plants such as deciduous oaks and flowering fruit trees.

The natural vegetation in which bryophytes are found is still present on much of the site. This includes Closed-forest dominated by Sassafras and Blackwood on basaltic soils on the southern slopes and in gullies; Tall Closed-forest dominated by Coachwood and Sassafras, restricted to sheltered deep gullies on sandstone with a downwash from basalt and shale. The diversity of bryophytes is highest in closed forests.

The elevation, and distance from the sea, provide Mount Tomah with a substantially higher rainfall (annual average 1541 mm) than most areas on the adjoining coastal plains (Rodd 1987b). Precipitation is generally highest in January and February (summer) when warm moist air mixes with the cooler air of the mountains. High rainfall and mists provide ideal conditions for the growth of bryophytes. In winter months rainfall is lower and cool clear days predominate. Occasionally day temperatures may not rise above 5°C and cool winds blowing from the Southern Highlands bring light snow (that melts quickly) on two or three days per year. Temperatures in summer are mild to warm ranging from 14°C–25°C in January but have reached as high as 36°C in 1985, and in winter (June–July) the average ranges from 3–10°C.

The bryophytes of Mount Tomah

Although the study of bryophytes was well advanced in Victoria by the mid 1800s, knowledge of the bryophytes in New South Wales and in particular in the Blue Mountains only started around the mid 1880s. In 1883 J. H. Maiden appointed W. Forsyth to take charge of the bryophytes at the National Herbarium of New South Wales (NSW). Within two years Forsyth had collected some 1200 specimens, many of which came from the Blue Mountains. The oldest specimens at the Herbarium from Mount Tomah are those of C. T. Musson (1886) and J. H. Maiden (1898). The earliest species obtained from Mount Tomah were *Dicranoloma dicarpum, Leptodon smithii, Fissidens pallidus, Pogonatum subulatum, Pyrrhobryum parramattense, Camptochaete ramulosa, Hypnodendron vitiense* subsp. *australe* (Forsyth 1899) (names quoted are their present ones). Since then few bryophyte specimens from Mount Tomah have been deposited at NSW until this study. All collections made for this study will be deposited at NSW for future reference.

The aim of the present study was to determine the species present and their distribution in the Garden in its early stage of development, as a basis for future studies. With this in mind several permanent sites have been set up for future analysis. These include selected limestone and basalt boulders and sections of the rock walls in exposed and shaded situations.

This preliminary list is presented as a basis for studies and comparison of individual bryophyte populations, and species richness over time.

In the future the bryoflora is likely to change both in species composition and in the area occupied by bryophytes as a result of dispersal by spores and fragments. Colonisation of bare rock, soil, the bark of trees and shrubs will occur as shade and humidity increase with time.

Species List

The list presented here (Table 1) includes bryophytes present at the end of May 1989. In most cases they represent species natural to the area but, where rock or soil has been imported, new species may have been introduced. Soil, rocks and plants imported for use in the gardens may have introduced spores and fragments of bryophytes with the ability to reproduce vegetatively. The trunks of imported tree ferns may have introduced some new species. Most of the rock associated with the gardens is local basalt but the limestone boulders came from a district on the western slopes. As a number of mosses grow only on limestones it will be interesting to see which species appear on the limestone boulders which at this stage are bare except for small colonies of *Tortula muralis.*

The list has been divided into two sections the garden area and rainforest area (identifications based on Scott & Stone 1976, Scott 1985, some recent literature and the collections at NSW).

The garden area

The garden area covers the crest of the mountain and includes a number of habitat types with respect to the bryophytes they support —

a. Stone walls built of local basalt.
b. Large rock outcrops, natural or constructed.
c. Imported limestone and calcareous habitats.
d. Exposed soil in lawns, garden beds and along paths.
e. Tree trunks and branches, tree fern trunks.
f. Wet or boggy areas e.g. cascade and *Sphagnum* bog.
g. Small rainforest on eastern side.

Bryophytes of the closed-forest on the northwestern side of Bells Line of Road

This remnant of the original rainforest occurs along both sides of a stream in a small gully. Open forest of *Eucalyptus* species adjoins the rainforest on the upper slopes. The habitats suitable for bryophytes are —

a. Rocks in the stream or wet soil on the bank
b. Rock surfaces or sheltered rock shelves in the forest.
c. Fallen tree and tree fern trunks.
d. Branches and trunks of living trees and shrubs.
e. Soil surfaces under rocky overhangs, on damp slopes.

Table 1. Checklist of bryophytes in the Mount Tomah Botanic Garden

(* New species record for Central Tablelands [CT] See Ramsay 1984. Name changes since Ramsay 1984a given in [].)

Species	Substratum	Location
THE GARDEN AREA		
MOSSES (***Bryopsida***)		
Barbula calycina	soil	front entrance
**Barbula* cf. *rehmannii*	soil	crevices, limestone boulders
Barbula unguiculata	soil	crevices, rock wall
Breutelia pendula	rock	near *Sphagnum* bog
Bryum argenteum	soil	crevices in rock walls and in paving
Bryum billardieri var. *billardieri*	soil	front *Rhododendron* garden
Bryum capillare	soil	basalt, with emergent boulders, picnic area
Bryum dichotomum	soil	crevices in front rock wall
		rock garden near cascade
Bryum sauteri	soil	rock garden near entrance, behind barbecue
Campylopus introflexus	soil	on occasional sandstone rock of front entrance wall
Ceratodon purpureus	soil	barbecue area and in crevices in front entrance wall
Dicranella dietricheae	soil	earth banks, roadside, with *Pogonatum subulatum*
Ditrichum difficile	soil	trackside bank, west side
Fabronia australis	bark	conifers, western side of service area
Fissidens leptocladus	soil	front *Rhododendron* garden
Funaria hygrometrica	soil	rock garden
Grimmia pulvinata var. *africana*	rock	exposed on basalt of front entrance wall
Hedwigidium integrifolium	rock, bark	boulders near picnic area, front entrance wall, trees (*Fraxinus*)
**Hypnum cupressiforme* var. *mossmannianum*	soil, bark	crevices in wall of path leading to conifer collection, tree fern trunks in eastern rain forest, *Cryptomeria* bark
Leptodon smithii	bark	*Juglans,* scree slope of rock garden
Leptostomum inclinans	bark	*Quercus*, northern lawn
Macrocoma tenue subsp. *tenue*	bark	exotic trees (*Fraxinus*), southern side of car park
Macromitrium ligulare	bark	exotic trees (*Juglans*) with *Leptodon smithii*
**Orthotrichum assimile*	bark	exotic trees
Papillaria flavo-limbata	bark, rock	tree branches, eastern rainforest, rocks near barbecue area
Philonotis tenuis	very wet soil	rock garden, near cascade

Species	Substratum	Location
Pogonatum subulatum	soil	earth banks, near front entrance
Ptychomitrium australe	rock	on basalt of front entrance wall, eastern rainforest, rock garden
**Sphagnum australe*	bog	in rock garden
Thuidium sparsum	rock, bark tree fern	on *Dicksonia antarctica*, eastern rainforest, front entrance wall
Tortula muralis	rock	entrance rock wall, limestone in rock garden
Tortula papillosa	bark	trunks of exotic trees (*Metasequoia*) with *Metzgeria, Macrocoma, Frullania*
Trachycarpidium brisbanicum	soil	rock garden
Weissia controversa	soil	crevices in front entrance wall
Wijkia extenuata	bark	trunks of conifers in conifer collection
LIVERWORTS (*Hepaticopsida*)		
Cephaloziella exiliflora	soil	mixed with moss (*Campylopus*) on sandstone face of front entrance wall
Chiloscyphus semiteres	rock	boulder behind barbecue area, eastern rainforest
Frullania clavata	bark	trunks of exotic trees, with *Macrocoma, Hedwigia, Metzgeria*
Frullania falciloba	bark	trunks of exotic trees (*Juglans*), top of rock garden, on (*Quercus*) in northern lawn
Frullania monocera	bark, tree fern	*Dicksonia antarctica*, exotic tree trunks (*Fraxinus*) with *Metzgeria, Hedwigia*
Frullania probosciphora	bark	trunks of exotic trees (*Fraxinus*)
Frullania squarrulosa	bark	trunks of exotic trees
Lejeunea drummondii	tree fern	*Dicksonia antarctica*, eastern rain forest
Lunularia cruciata	soil	rock garden
Marchantia polymorpha var. *aquatica*	soil	between boulders in rock garden
Metzgeria decipiens	bark	tree ferns, trunks of exotic trees (*Metasequoia, Cryptomeria*) with *Macrocoma, Tortula papillosa*
Metzgeria furcata	bark	trunk of Beech (*Fagus*) in northern lawn on *Metasequoia*, with *Metzgeria, Macrocoma, Tortula papillosa*
Porella crawfordii	rock	boulders near barbecue area

Species	Substratum	Location
THE RAINFOREST (RF)		
MOSSES (***Bryopsida***)		
Achrophyllum dentatum	rock	near stream
Barbula calycina	soil bank	above RF
Camptochaete arbuscula	rock	wet sandstone boulder in RF *Ceratopetalum* & *Doryphora* and near stream
Camptochaete gracilis	rock	near stream
Camptochaete vaga	rock, bar	boulders, rock outcrops
Campylopus introflexus	soil, rock	in more open areas of forest
Ceratodon purpureus	soil	colonising roadside earth bank above rainforest
Cryphaea exannulata	bark	tree branches near edge of RF
Dawsonia polytrichoides	soil	disturbed soil on track above RF
Dicranoloma serratum	bark	tree, edge of RF
Ditrichum difficile	soil	earth bank above RF
Fissidens humilis	soil	shaded bank
Fissidens leptocladus	soil	shaded bank
Fissidens pallidus	soil	shaded earth banks in open forest of *Eucalyptus fastigiata,* under rock outcrops & fallen logs
Fissidens taylorii	soil	shaded bank near stream
Hampeella pallens	bark	tree trunks and branches
Hypnodendron vitiense subsp. *australe*	soil, rock	in or near stream
**Hypnum cupressiforme* var. *filiforme*	bark	tree branch on shaded bank above stream
**Hypnum cupressiforme* var. *mossmannianum*	bark	on trunk of *Doryphora sassafras*
Hypopterygium rotulatum	rock	in and near stream
Leptodon smithii	bark	on trunks of trees well above stream
Leptostomum inclinans	bark	high on upper trunk of *Doryphora sassafras*
Macrocoma tenue subsp. *tenue*	bark	above stream
Macromitrium archeri	bark	tree branches, edge of RF
Macromitrium involutifolium	tree fern	*Dicksonia antarctica,* edge of RF
Macromitrium ligulare	bark	tree branches, edge of RF
Mittenia plumula	soil	shaded bank near stream
Papillaria amblyacis	bark, rock	tree branches, dense part of forest near stream
Papillaria crocea	bark, rock	tree branches, dense part of forest near stream
Papillaria flavolimbata	bark, rock	tree branches, dense part of forest near stream

Species	Substratum	Location
Papillaria flexicauli	rock, bark	festooning shrubs
Philonotis tenuis	soil, rock	wet sandstone weeping wall shaded moist earth banks
Pogonatum subulatum	soil	roadside earth bank above RF
Pyrrhobryum parramattense	rock, bark	rocks in stream, bases of trees
Racopilum cuspidigerum var. *cuspidigerum*	rock, bark	rocks in stream, fallen logs
Rhaphidorrhynchium amoenum	rock, bark	fallen logs
Rhynchostegium tenuifolium	bark	rotten, fallen logs
Schizomeria bryoides [Mielichhoferia bryoides]	soil	earth bank
Sematophyllum contiguum	soil	gully above stream
Thuidium cymbifolium	rock	above & near stream
Thuidium sparsum	rock	above & near stream
Wijkia extenuata	bark	tree trunks, fallen logs, stumps
HORNWORTS (*Anthocerotopsida*)		
Megaceros gracilis	rock, soil	stream & stream bank
LIVERWORTS (*Hepaticopsida*)		
Balantiopsis diplophylla	soil	stream bank with *Lepidozia, Chiloscyphus, Telaranea*
Chiloscyphus argutus	soil	stream bank, with *Lepidozia, Balantiopsis, Telaranea*
Frullania falciloba	bark	with other *Frullania* species on trees on outer edge of RF
Frullania monocera	bark	with other *Frullania* species on trees on outer edge of RF
Frullania pentapleura	bark	with other *Frullania* species on trees on outer edge of RF
Frullania probosciphora	bark	with other *Frullania* species on trees on outer edge of RF
Frullania squarrulosa	bark	with other *Frullania* species on trees on outer edge of RF
Hymenophyton flabellatum	soil, rock	near stream
Lepidozia laevifolia	soil	shaded bank
Metzgeria decipiens	tree fern	*Dicksonia antarctica*
Porella crawfordii	bark	exposed tree root
Symphyogyna podophylla	soil	moist shaded bank, near stream
Telaranea dispa	soil	stream bank, with *Lepidozia, Balantiopsis, & Chiloscyphus*
Tylimanthus tenellus	tree fern	*Dicksonia antarctica* with *Macromitrium involutifolium*

Discussion

Representatives of three classes of bryophytes, mosses (Bryopsida), hornworts (Anthocerotopsida), and liverworts (Hepaticopsida) occur in the gardens and natural forests of the Mount Tomah Botanic Garden. The wide variety of substrata available and the range of vegetation types have created habitats for a particularly diverse group of species. Bryophytes are most conspicuous in the closed-forests on the eastern slopes of the gardens and in the gully on the north western side of Bells Line of Road. The relatively cool and moist climate of Mount Tomah, combined with shade from the dense canopy of rainforest trees, protects bryophytes from desiccation by sun and wind. Bryophytes are found growing as colonisers of bare soil, rocks, fallen logs, as epiphytes on trunks of trees and tree ferns, branches or even the surface of leaves. They thrive on sheltered earth banks, and on rocks in or near streams and waterfalls. In providing a habitat for invertebrates, micro-algae and fungi they contribute to the eventual decomposition of fallen logs. Their ability to survive on exposed situations on soil, earth banks, rocks and walls as well as tree trunks is possible because of their xeromorphic and xerophytic adaptations to desiccation. Their presence often accelerates the weathering of rocks.

This preliminary list of 85 bryophytes includes 63 mosses, 21 hepatics and 1 anthocerote (hornwort): 35 mosses and 13 hepatics were collected from the main garden, 43 mosses, 14 hepatics and 1 anthocerote (hornwort) from the rainforest. Of these, 14 mosses and 6 hepatics occur throughout the garden; 28 mosses and 8 hepatics occur only in the rainforest and 20 mosses and 6 hepatics occur only in the gardens area. There are several new records of mosses for the CT region *Barbula* cf *rehmannii, Orthotrichum assimile, Racopilum cuspidigerum* var. *cuspidigerum, Hypnum cupressiforme* var. *filiforme,* and recent studies have eliminated *Thuidium furfurosum* from the area as specimens have been reidentified as *T. sparsum* (Touw & Haak 1990). Other name changes are indicated in the check list. Without any previous knowledge of hepatics present it is not possible to comment on them.

The species common throughout the gardens include colonisers of soil or rock such as *Bryum argenteum, B. dichotomum, Campylopus introflexus, Ceratodon purpureus, Fissidens* spp., *Pogonatum subulatum, Tortula muralis,* or epiphytes such as *Chiloscyphus semiteres, Frullania* spp., *Macrocoma tenue, Macromitrium ligulare, Thuidium sparsum, Wijkia extenuata.* Species found only in the shaded rainforest include those common on wet ground near streams e.g. *Camptochaete* sp, *Hypnodendron vitiense, Dawsonia polytrichoides, Hypopterygium rotulatum,* or epiphytes e.g. *Papillaria* sp, *Macromitrium* sp, *Dicranoloma serratum.* One species, *Sphagnum australe,* is known to be introduced.

While Mount Tomah occupies a mere 31 hectares in the Blue Mountains which form the northernmost limit of the Central Tablelands area (CT) of New South Wales (Anderson 1961, Ramsay 1984b), it is of interest to relate our findings to the bryoflora for the region. Ramsay (1984a, b) lists 90 genera and 203 species of mosses for the Central Tableland (CT) representing 38.3% N.S.W. species. Only mosses have been listed previously and there is no species list for hepatics for CT. Stephani & Watts (1914) described at least 25 species of hepatics based on specimens from the Blue Mountains.

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The natural vegetation of the Wallerawang 1:100 000 map sheet

D.H. Benson and D.A. Keith

Abstract

Benson, D.H. & Keith, D.A. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1990. The natural vegetation of the Wallerawang 1:100 000 map sheet. Cunninghamia 2(2): 305–335.* The composition and extent of the present natural vegetation on the Wallerawang 1:100 000 map sheet 8931 (lat. 30°00′– 33°30′S, long. 150°00′–150°30′E) are described and mapped from aerial photography and field traverses. The structure, characteristic species, and associated environmental factors for 18 map units with 29 plant communities are described. These communities include small areas of eucalypt tall open-forest, extensive tracts of open-forest and woodland, and localised patches of sclerophyllous heath and shrub swamp.

The vegetation patterns are influenced by geology (mainly sedimentary and metasedimentary rocks), soil types (mainly low nutrient acid soils) and physiography (dissected sandstone plateaus and deep gorges), as well as modified by elevation (ranging from 400 m to almost 1200 m above sea level) and rainfall (ranging from 620 mm to 1220 mm per annum).

Significant plant communities and 23 rare species are listed. There is a need to conserve representative samples of plant communities on the western side of the map sheet and on the high elevation Newnes Plateau in particular, where proposals for extensive sand extraction threaten important woodlands, heaths and swamps. Particular concentrations of rare species occur on the Newnes Plateau, and in the Capertee Valley near Glen Davis. These areas may represent refugia during periods of climatic change.

Introduction

Massive orange sandstone cliffs, spectacular ‘pagoda’ country, the dry woodlands of the Wolgan and Capertee valleys, and a history of often isolated and short-lived mining and industrial activity in a harsh natural environment, provide the background to the different plant communities in this map sheet area.

The Wallerawang 1:100 000 Vegetation Map Sheet (based on Wallerawang 1:100 000 Topographic Sheet 8931, Royal Australian Survey Corps) is bounded by latitudes 33°00′–33°30′S, and longitudes 150°00′–150°30′E. It is located in the Central Tablelands botanical subdivision of New South Wales except for part of the north-east corner which is in the Central Coast subdivision. It is about 100 km north-west of Sydney and is due north of the Katoomba sheet (Keith & Benson 1988).

Geology and geomorphology

The Wallerawang map sheet area lies on the western edge of the Sydney Basin, a major geological structural basin extending from Muswellbrook to Batemans Bay. The Great Dividing Range is on the western edge of the map sheet, and most of the sheet is within its eastern watershed. The major rivers are the Wollangambe, Wolgan and Capertee which flow eastward to join the Colo River and thence the Hawkesbury, and the Coxs River which flows to the south and ultimately eastward also to the Hawkesbury (Figure 1). The highest part of the map sheet, the Newnes Plateau (1100–1200 m) is a residual plateau of friable sandstones and shales of the Triassic Narrabeen Group (N.S.W. Department of Mines 1966). Evidence of remnant aeolian sand dunes has been recently observed (M. Tulau pers. comm.). Swamps have formed in the low relief headwater valleys of the Newnes Plateau, as a result of the high rainfall, low slope and impeded runoff. These swamp-filled valleys relate to NNE-SSW trending geological lineaments, and contrast markedly in orientation with the deeply incised easterly drainage patterns developed elsewhere throughout the Blue Mountains (Pecover 1984). Characteristic features of the Plateau margins are the 'pagoda' or beehive-shaped sandstone formations formed from the differential weathering of hardened layers of ironstone and softer sandstone strata.

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Further east is an expansive dissected sandstone country, the 'Colo Wilderness' of Gold & Prineas (1978), a maze of ridges and gullies, of rocky outcrops and deep canyons cut from Narrabeen Group sandstones or the similarly appearing Triassic Hawkesbury Sandstones which cap them on the eastern fringe of the map sheet. Drainage is to the east. The southern half is known appropriately as the Wollangambe Wilderness. There are small Tertiary basalt flows capping the sandstone plateaus at Mount Irvine, Mount Cameron and Gospers Mountain,

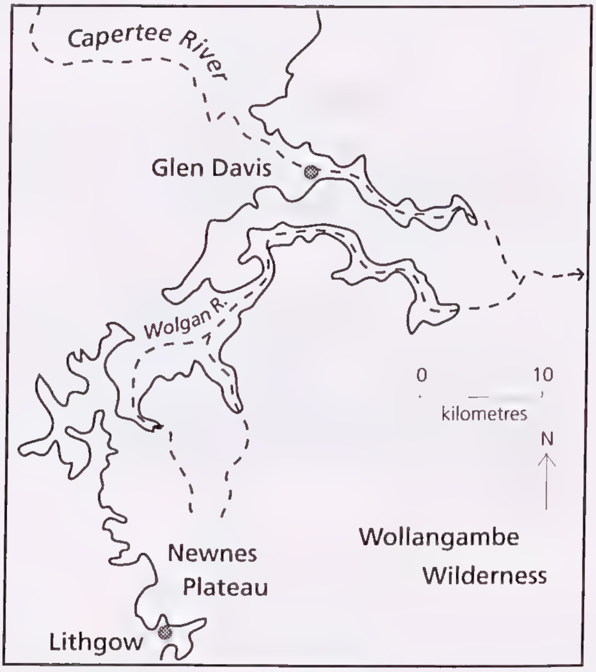

Figure 1. Major geographical features on the Wallerawang map sheet. Unbroken line indicates the western margin of main Triassic plateau.

and also on Mount Airly and Genowlan Mountain in the Capertee Valley.

West and north of the Newnes Plateau, the main rivers have cut through the sandstone to expose the softer Permian Illawarra Coal Measures and Shoalhaven Group below. The valleys of the Capertee and Wolgan Rivers are characterized by undulating floors between long talus slopes surmounted by spectacular sandstone cliffs. Isolated flat-topped mesas, Pantoneys Crown, Donkey Mountain, Mount Gundangaroo and Mount Airly, are impressive features within these valleys.

In Coco and Airly Creeks, in the north-west of the map sheet, deeper erosion of the valley floors has taken place. Here the underlying shales, siltstones, quartzites, tuffs and limestones of Devonian age are exposed. Similar Devonian metasediments, though lacking limestone, are exposed around Mount Walker (1137 m) west of Lithgow, and have eroded to leave very rugged country. Small areas of Carboniferous adamellite, granite and granodiorite (part of the Kanimbla Batholith) outcrop south-west of Wallerawang and west of Lithgow. A small diorite intrusion outcrops near Ben Bullen.

Climate

The map sheet area includes some of the highest parts of the Blue Mountains and a section of the Great Dividing Range. Average maximum temperatures for January, the hottest month, are 25.4°C at Lithgow (920 m elevation), 23.5°C at Newnes State Forest (1024 m) and up to 27°C in the Capertee Valley (300 m). Average minimum temperatures for July, the coldest month, are 0.5°C at Lithgow and −1.0°C at Newnes State Forest. The lowest recorded minimum temperature for Lithgow has been −12.1°C in June (Bureau of Meteorology 1979).

Rainfall is highest over the Newnes Plateau and the high country in the south-eastern corner of the map sheet (Mount Wilson, just outside to the south receives 1228 mm p.a.), and decreases with decreasing elevation northward (Newnes State Forest 1047 mm p.a.) to less than 900 mm at the northern edge of the sheet. As a result of a rainshadow effect, there are lower rainfalls in the major valleys, the Capertee, the Wolgan and the Coxs. Lithgow, in the Coxs valley receives 888 mm per annum, and the lower elevation (320 m) Glen Alice in the Capertee valley further north receives only 621 mm. Seasonality is consistent throughout the area, with most rain falling between January and March; July and August are the driest months.

Light snow may fall at altitudes above about 1000 m, most frequently in July or August. Mount Victoria (1064 m), on the plateau just south of the map sheet averages ten snowfalls per year though Lithgow, below the escarpment, receives only three (Bureau of Meteorology 1979).

Soils

Soils on the low-relief sandstone plateaus are mainly sandy, yellow, leached, gradational soils with ironstone gravels (Hamilton 1976). Grey-brown and yellow-brown uniform sands are found on areas of stronger relief. These soils are acidic and very infertile. In some of the headwater valleys on the Newnes Plateau and in the headwaters of Coxs River, below the escarpment, swampy, organic, highly acidic sediments have accumulated. Soils on the steep Permian slopes are yellow leached gradational sandy loams; hard-setting, texture-contrast, sandy loams are found on flatter sites. Infertile, shallow, loamy, yellow, leached gradational soils are found on the Devonian sediments, while sandy loam red-brown gradational soils of moderate fertility relate to granite parent material (Hamilton 1976). Very fertile clay-loam, brown and red structured friable soils are found on the basalt caps.

Land use

Lithgow and Wallerawang, both in the south-west corner of the map sheet, are the major towns; smaller settlements, Cullen Bullen, Ben Bullen and Glen Alice lie further north. With the exception of the Lithgow valley, the area is sparsely settled, and includes extensive State Forest and National Park areas.

Underground mining of the Permian/Illawarra Coal Measures for coal has been a major industry since the arrival of the western railway in 1869. New mines, along the western Newnes Plateau have been developed particularly for electricity generation. Lithgow developed as a mining and industrial town, and today is one of the largest on the Central Tablelands. A short-lived shale oil industry had its heyday in the early 1900s, ceasing in the 1940s. Ruins at Newnes and Glen Davis, and in particular the abandoned Newnes Railway stand testament to the major engineering feats needed to overcome the rugged terrain. The Newnes Railway also provides an interesting botanical link as the chief engineer during construction, Henry Deane, was also an enthusiastic amateur botanist who, amongst other things, collected the first specimens of *Boronia deanei*, presumably while surveying for the railway. After its abandonment the railway route provided access for naturalists into much otherwise inaccessible country including the Glowworm Tunnel.

Forestry operations at Capertee, Ben Bullen and Lidsdale State Forests, west of the escarpment, and Newnes State Forest on the Newnes Plateau, mainly provide hardwood pit-props for the coal mines from the native forests, and pine logs from *Pinus radiata* plantations first established in the 1930s.

The extensive deposits of deeply weathered friable sandstone on the Newnes Plateau have been suggested as a major source of industrial and construction sand for Sydney (Pecover 1984) and there are already major sand quarries at Clarence.

Nature conservation is a major landuse on the lower elevation sandstone country on the eastern half of the map sheet which includes parts of Wollemi and Blue Mountains National Parks.

Vegetation

Methods

Areas of vegetation with similar structural (Specht 1970) and floristic characteristics (dominant species) were grouped to form the map units on the basis of aerial photopatterns and available geological and landscape characteristics. Black and white 1975 aerial photographs from the New South Wales Department of Lands (approx. scale 1:40 000) were used. Only existing (i.e. in 1975) natural vegetation is mapped, though comments on the original natural vegetation of some agricultural and urban areas are provided. An alpha-numeric code is used to identify individual map units. The numeric code represents the Specht structural form of the plant community and the alphabetic code represents the characteristic species. The codes used are consistent throughout the Sydney Region 1:100 000 Vegetation Map Series allowing map units to be cross referenced (Benson 1986, Keith & Benson 1988).

Compilation maps were prepared at 1:25 000 scale and subsequently reduced to 1:100 000 scale. Dyeline copies of the 1:25 000 compilation map sheets, Ben Bullen, Cullen Bullen, Gospers Mountain, Glen Alice, Lithgow, Mount Morgan, Rock Hill and Wollangambe may be obtained from the Director, Royal Botanic Gardens, Sydney.

The map units recognized are not all of equivalent rank. Limitations of scale and the difficulty of separating different species groupings with the same structural form make this impossible, except where very detailed ground traverses are done. Some units are essentially land units made up of several plant communities associated with a particular geological or physiographic type (e.g. map units 10a and 10h), whereas others are more clearly plant associations (sensu Beadle & Costin 1952) (e.g. map unit 9j). Generally the term 'plant community' is used for the basic vegetation unit. Where vegetation boundaries are relatively distinct, they are mapped with an unbroken line, while more diffuse boundaries are mapped with a broken line. For ease of reference, an attempt has been made to provide common names for communities, based loosely on habitat and composition.

General knowledge of the vegetation had been previously gained during the course of a number of localized surveys, but specific field checking was conducted mainly during the period 1978–1981. This included collection of lists of species from a number of 20 x 20 m sites. The reliability diagram on the map indicates where more detailed reconnaissance and site data collection was concentrated. As the patterns shown on the map are derived essentially from air photo interpretation and geological patterns, the map's overall pattern is not strongly biased by the degree of access available. Increased fieldwork in the more remote areas however would increase the accuracy of some of the map unit descriptions, as well as providing worthwhile data on localized features and species.

Information from unpublished reports of these local surveys has been included and the reports not cited individually unless they provide additional information. Reference has been made to existing plant community descriptions or species lists. Exhaustive species lists are not included here, though local species lists compiled at the National Herbarium are available (e.g. Bryant & Benson 1981; Keith 1988). A provisional list of species for the map sheet recorded during fieldwork is provided on the back of the map sheet. A list of species of particular conservation significance was prepared from herbarium records and fieldwork.

Botanical names used are those currently recognized at the National Herbarium of New South Wales. Recent nomenclatural changes include revisions of *Leptospermum* (Thompson 1989), *Banksia* (George 1981), *Tristania* (Wilson & Waterhouse 1982) and the separation of *Allocasuarina* from *Casuarina* (Johnson 1982).

The general vegetation of the Triassic sandstone has been described in

Pidgeon's (1937, 1938, 1940, 1941) vegetation study of the Central Coast of New South Wales. Broader views of the vegetation patterns are given in Beadle (1981) and Forster (1981).

A summary of the map units recognized here, their structural formation, main canopy species and geological substrate are given in Table 1. The vegetation map is located inside the back cover. This map and text replace an earlier draft map (Benson 1984).

Descriptions of map units shown on the Wallerawang sheet

The map unit numbering system applies to the Sydney Region Vegetation Map Series. Missing numbers are used for plant communities not found on the Wallerawang sheet.

Map unit 6g – 'Moist Basalt Cap Forest'

Tall open-forest: *Eucalyptus viminalis – E. blaxlandii*

This unit is confined to the rich fertile soils on basalt-capped mountains receiving a reasonably high annual rainfall (>900 mm). These isolated peaks rise slightly higher than the surrounding sandstone plateaus. They include Mount Irvine, Mount Cameron, Green Hill and Gospers Mountain and may be up to 1000 m high. The largest area of this vegetation is at Mount Wilson, just to the south of the map sheet, and described by Brough, McLuckie & Petrie (1924), Petrie (1925) and McLuckie & Petrie (1926). Their descriptions are relevant to vegetation on the basalt caps further north, though the smaller basalt-capped peaks such as Tambo Limb are less diverse. Typically on peaks with adequate rainfall (>900 mm) there is tall open-forest of *Eucalyptus viminalis* and *E. blaxlandii*, less commonly *E. fastigata*, some trees being up to 40 m high, with smaller trees of *Eucalyptus radiata* subsp. *radiata* and *Acacia melanoxylon* (Figure 2). The understorey has grasses, herbs and ferns, and small shrubs. Common ground layer species are *Pteridium esculentum, Viola hederacea, Dichondra repens, Geranium homeanum, Acaena novae-zelandiae, Hydrocotyle laxiflora* and *Polystichum proliferum.* Large clumps of *Libertia paniculata* are common and particularly prominent when flowering. Scattered clumps of shrubs, generally very prickly ones, are conspicuous; common species are *Coprosma quadrifida, Daviesia ulicifolia* and *Bursaria spinosa.*

On sheltered southern aspects and along watercourses, rainforest elements are present, though rarely as well developed as on Mount Wilson. Certainly the rich fern flora of Mount Wilson is not repeated elsewhere. On Mount Cameron, for instance, are trees of *Doryphora sassafras, Acacia melanoxylon* and *Hedycarya angustifolia*, the tree fern *Cyathea australis* and a dense understorey of moist forest species including *Coprosma quadrifida, Clematis glycinoides, Tylophora barbata* and *Eustrephus latifolius*. On the transition from the basalt soils to the surrounding sandstone, drier open-forest with *Eucalyptus cypellocarpa* and a dense shrub layer of *Bursaria spinosa* and *Daviesia ulicifolia* may be found.

The fertile soils on the basalt caps were eagerly sought by the early settlers for grazing and farming and many were totally or partially cleared. At the end of the nineteenth century they were linked by a network of often-steep bridle paths. Many of the most isolated ones have now been abandoned, or included within National Park allowing the vegetation to regrow.

Table 1. Map unit, common name, structure, main canopy species, geology, altitude and habitat of plant communities shown on Wallerawang 1:100 000 map sheet.

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
6g	**'Moist Basalt Cap Forest'**				
	Tall open-forest	*Eucalyptus viminalis* *E. blaxlandii*	Tertiary basalt	>800m	Isolated residual caps eg. Mt Cameron
9i	**'Blue Mountains Sandstone Plateau Forest'**				
	Open-forest	*Eucalyptus sieberi* *E. piperita*	Narrabeen Group	800-1150m	Sandstone plateaus and ridges
9j	**'Montane Gully Forest'**				
	Open-forest	*Eucalyptus fastigata* *E. cypellocarpa* *E. dalrympleana*	Narrabeen Group	850-1150m	Gorges and sheltered gullies
10ag	**'Sydney Sandstone Gully Forest'**				
	Open-forest	*Angophora costata* *Eucalyptus piperita* *E. agglomerata*	Narrabeen Group Hawkesbury Sandstone	<800m	Valleys and lower slopes
10ar	**'Sydney Sandstone Ridgetop Woodland'**				
	Woodland	*Eucalyptus gummifera* *E. oblonga* *E. sclerophylla*	Narrabeen Group Hawkesbury Sandstone	<800m	Plateaus and ridges at lower altitudes
	Open-forest	*E. beyeri* *E. punctata*			
10f	**'Newnes Plateau Woodland'**				
	Woodland	*Eucalyptus sieberi* *E. oreades* *E. dives*	Narrabeen Group	>1050m	High altitude plateau Newnes State Forest
10g	**'Scribbly Gum-Stringybark Woodland'**				
	Woodland	*Eucalyptus rossii* *E. oblonga*	Narrabeen Group	>800m	Sandstone plateaus and ridges with lower rainfall than 9i
10h	**'Tablelands Grassy Woodland Complex'**				
	Woodland	*Eucalyptus rossii* *E. macrorhyncha*	Permian Illawarra Group	>800m	Hilly country, dry aspects
	Woodland	*E. mannifera* *E. dives*			Undulating to hilly country
	Open-forest	*E. dalrympleana*			Alluvium in valleys
	Woodland	*E. pauciflora* *E. rubida*			Valleys with frost hollows

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
10i	**‘Talus-slope Woodland’**				
	Woodland	*Eucalyptus rossii* *E. macrorhyncha* *E. polyanthemos* *E. fibrosa*	Permian Illawarra Group	200-900m	Talus of major valleys, exposed sites
	Open-forest	*E. cypellocarpa* *E. eugenioides* *E. punctata* *E. melliodora*			Sheltered sites
10j	**‘Capertee Valley Woodland’**				
	Woodland	*Eucalyptus melliodora* *E. blakelyi* ± *E. albens* ± *E. crebra*	Permian Shoalhaven Group	300-700m	Possibly limestone influenced
	Woodland	*Eucalyptus fibrosa* *E. crebra* ± *E. rossii* ± *E. oblonga*			Dissected plateaus
10k	**‘White Box Woodland’**				
	Woodland	*Eucalyptus albens* *Brachychiton populneus*	Devonian shale, siltstone quartzite, tuff, limestone	400-600m	Gorges of Airly, Coco and Genowlan Creeks
	Woodland	*Angophora floribunda* *E. melliodora*			Alluvial/ colluvial soils, riverine
10m	**‘Mt Walker Complex’**				
	Woodland	*Eucalyptus dives* *E. mannifera* *E. bridgesiana* *E. rossii*	Devonian Lambie Group; quartzites, sandstones, siltstones, claystones	>600m	Rugged country around Mount Walker
10n	**‘Dry Basalt Cap Woodland’**				
	Woodland	*E. polyanthemos* *E. macrorhyncha*	Tertiary basalt	>1000m	Residual caps on sandstone mesas and plateaus
11a	**‘Open Mottled Gum Woodland’**				
	Open-woodland	*Eucalyptus mannifera* *E. dives* *E. pauciflora* ± *E. radiata*	Narrabeen Group	>900m	Poorly-drained creeks and shallow valleys, often surrounding shrub-swamps

Map unit	Structure	Main canopy species	Geology	Altitude	Habitat
20a	**'Newnes Plateau Shrub Swamps'**				
	Closed-heath	*Leptospermum grandifolium* *Baeckea linifolia* *Grevillea acanthifolia*	Narrabeen Group alluvium	>1000m	Shrub-swamps in narrow headwater valleys
	Sedgeland	*Gymnoschoenus sphaerocephalus* *Xyris ustulata*			
20b	**'Coxs River Swamps'**				
	Closed-heath	*Leptospermum obovatum* *L. continentale*	Alluvium	>600m	Valleys and headwaters of creeks
	Sedgeland	*Carex* spp.			
21c	**'Montane Heath'**				
	Open-heath	*Allocasuarina nana* *Banksia ericifolia* *Leptospermum attenuatum* *Phyllota squarrosa*	Narrabeen Group	>850m	Exposed sites on shallow sandy soils
21d	**'Pagoda Rock Complex'**				
	Open-heath	*Allocasuarina nana* *Leptospermum arachnoides* *Lepidosperma viscidum*	Narrabeen Group	>750m	Exposed sites on rock outcrops with shallow soils
	Open-scrub	*Eucalyptus* sp. nov. MOKII			Associated with extensive rocky platforms and 'pagoda' rock formations
	Woodland	*E. rossii* *E. piperita*			Small sheltered gullies

C Cleared Native vegetation has been largely removed for agricultural, industrial or urban development but remnant vegetation of varying sizes and condition may remain.

Map unit 9i – 'Blue Mountains Sandstone Plateau Forest'

Open-forest: *Eucalyptus sieberi – E. piperita*

This vegetation is characteristic of the Upper Blue Mountains, from Wentworth Falls to Bell and on much of the eastern Newnes Plateau. Varying structurally from open-forest to woodland, it predominates on the sandstone plateaus and ridges between 800 and 1050 m elevation with a rainfall between 900 and 1400 mm p.a. Soils are grey and yellow-brown uniform sands, very acid, well-drained and chemically very infertile (Hamilton 1976).

The dominant trees are *Eucalyptus sieberi* and *E. piperita* subsp. *piperita*, often with *E. radiata* subsp. *radiata* (Figure 3). *Eucalyptus mannifera* subsp. *gullickii* is common on poorly-drained sites and *E. sclerophylla* on exposed sites. Both may form pure stands in these respective conditions. Stringybarks, *E. blaxlandii* and *E. oblonga*, may be present – *E. blaxlandii* on the most sheltered sites at higher elevations, and *E. oblonga* on more exposed sites.

The understorey is dominated by shrubs 1 to 2 m high. Many of the species are widespread on sandstone around Sydney, while others are restricted to the higher elevations. Common species are *Lomatia silaifolia, Platysace linearifolia, Acacia terminalis, Amperea xiphoclada, Persoonia laurina* and *Hakea dactyloides.* Typical high altitude species include *Acacia dorothea, Daviesia latifolia, Banksia spinulosa* var. *cunninghamii, Phyllota squarrosa, Persoonia myrtilloides* and *Boronia microphylla. Telopea speciosissima* may be locally common on deeper soils, while *Lomandra glauca* and *Patersonia glabrata* are common groundcover species.

Map unit 9j – 'Montane Gully Forest'

Open-forest: *Eucalyptus fastigata – E. cypellocarpa – E. dalrympleana*

Open-forest of *Eucalyptus fastigata* and *E. dalrympleana* subsp. *dalrympleana* is found at high elevations (above 850 m) on escarpment slopes around Lithgow. It is found in narrow gorges and canyons at the edges of the sandstone

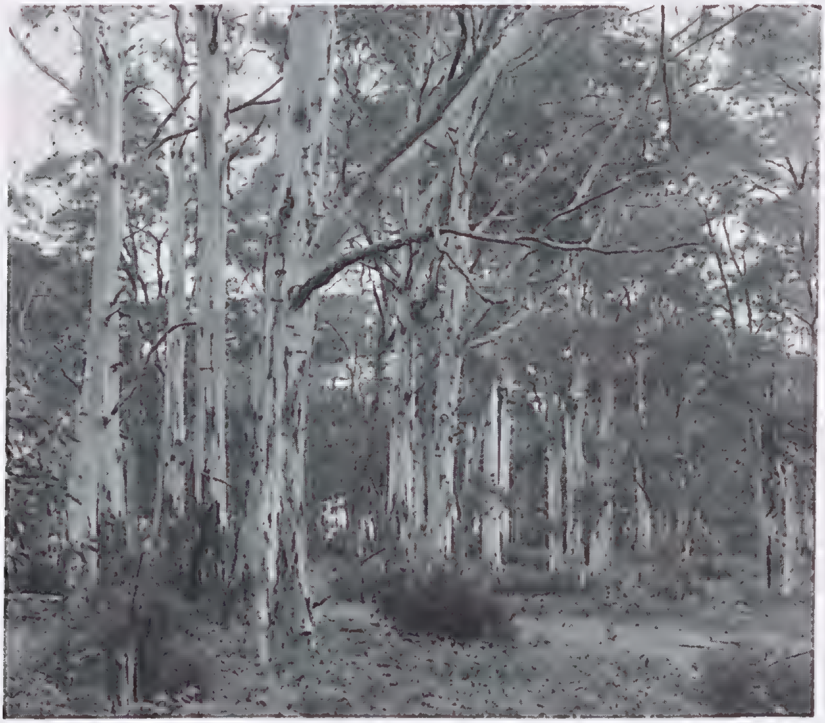

Figure 2. 'Moist Basalt Cap Forest' (map unit 6g) with *Eucalyptus viminalis* and an understorey of *Pteridium esculentum* and herbs at Mount Cameron.

plateaus, and at the heads of major drainage systems such as the Wolgan and Carne Creek. These are all sheltered sites and the soils, although of only low to moderate fertility, are moist, well-drained and deep, enriched by colluvial material from the sandstone escarpments above. Tree height now is commonly about 20 m, but most of these forests have been logged though there are still pockets of big trees in inaccessible gullies. The main species are *Eucalyptus fastigata* and *E. dalrympleana*, though *E. oreades* and *E. piperita* subsp. *piperita* may also be present on drier sites. The understorey has a sparse shrub stratum often with *Acacia dealbata, A. buxifolia, Cassinia* sp., *Leptospermum flavescens, Oxylobium ilicifolium* and *Banksia spinulosa* var. *cunninghamii*. Ferns *Pteridium esculentum* and *Blechnum* sp., herbs *Lomandra longifolia, Viola betonicifolia, Stellaria flaccida, S. pungens*, and *Acaena novae-zelandiae*, and twiners *Clematis aristata* and *Billardiera scandens* make up the continuous groundcover.

Along the creeks associated with this community is shrub swamp, similar to that of the swamps on the plateau (map unit 20a). Common shrub species are *Leptospermum lanigerum, L. obovatum, Baeckea linifolia* and *Grevillea acanthifolia* subsp. *acanthifolia* together with the graminoids *Gahnia subaequiglumis, Restio australis, Juncus continuus* and *Empodisma minus.*

Map unit 10a – 'Sydney Sandstone Complex'

The widespread and distinctive vegetation complex found on the low elevation coastal Sydney sandstone plateaus reaches its western limit on the Wallerawang

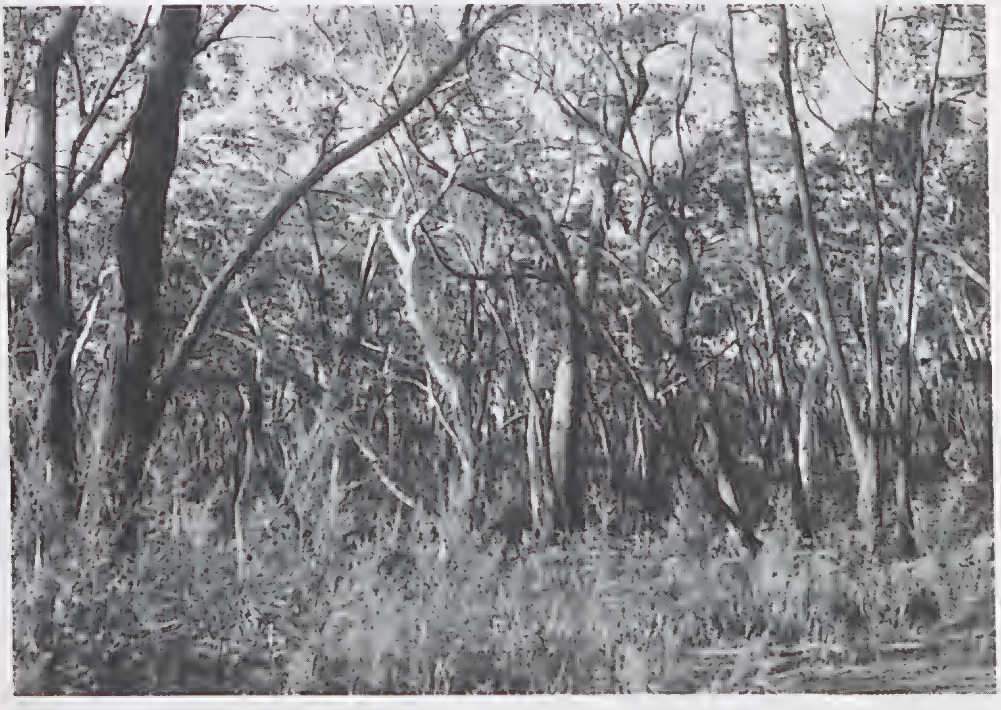

Figure 3. 'Blue Mountains Sandstone Plateau Forest' (map unit 9i) with *Eucalyptus sieberi–E. piperita* on the eastern side of the Newnes Plateau. Note the lack of straight stems and multi-stemmed nature of many individuals.

map sheet where it is found on sandstones of both the Hawkesbury Formation and the Narrabeen Group. Soils here are low-nutrient grey and yellow-brown uniform sands as found elsewhere on the sandstone (Hamilton 1976), but the increasing elevational and decreasing rainfall gradients from east to west influence floristic composition. For example, the trees *Angophora costata, Eucalyptus gummifera* and *E. eximia* are gradually replaced further west by *E. sieberi* and *E. consideniana.*

On a local scale, variation relates to changes in physiography, aspect, soil depth and texture, and available moisture. Repeating patterns are evident in the topography and two broad subunits can be recognised: the moist forest associated with gullies and sheltered slopes (10ag); and the drier woodlands of the ridges and plateau (10ar). There is considerable floristic overlap between these subunits and both grade into the higher altitude 'Blue Mountains Sandstone Plateau Forest' (map unit 9i) above 800 m elevation.

Subunit 10ag – 'Sydney Sandstone Gully Forest'

Open-forest: *Angophora costata – E. piperita – E. agglomerata*

'Gully Forest' occurs in sheltered gullies with moist, well-drained, sandy soils. Trees of *Angophora costata, E. piperita* subsp. *piperita* and *E. agglomerata* less commonly with some *E. punctata* and *Syncarpia glomulifera*, up to 25 m high form an open-forest community. The understorey is mainly of shrubs to 2 m tall; *Leptospermum flavescens, Banksia spinulosa* var. *collina, Persoonia levis, P. linearis, Hakea dactyloides* (single-stemmed form), *Pultenaea flexilis, P. scabra* var. *scabra, Dillwynia retorta, Acacia obtusifolia, Platysace linearifolia, Leucopogon lanceolatus* var. *lanceolatus* and *Epacris pulchella*, with a groundcover of *Dianella caerulea, Lomandra gracilis, Gonocarpus teucrioides* and *Pteridium esculentum.*

Subunit 10ar – 'Sydney Sandstone Ridgetop Woodland'

Woodland: *Eucalyptus gummifera – E. oblonga – E. sclerophylla*

Open-forest: *Eucalyptus beyeri – E. punctata*

'Ridgetop Woodland' is found on ridges, open slopes and plateau surfaces with shallow, well-drained, sandy soils that are very infertile. The most common trees are *Eucalyptus gummifera, E. sclerophylla, E. oblonga, E. consideniana,* and occasionally *Angophora costata.* The understorey is predominantly shrubby with *Banksia spinulosa* var. *collina, Hakea dactyloides* (multi-stemmed form), *Lomatia silaifolia, Grevillea sericea, Persoonia linearis, Bossiaea rhombifolia, Phyllota squarrosa, Daviesia ulicifolia, Acacia linifolia, Platysace ericoides, P. linearifolia* and *Hibbertia acicularis. Lomandra obliqua, Caustis flexuosa, Entolasia stricta* and *Stipa pubescens* make up a sparse groundcover.

On flatter areas of the plateau, deeper clay loams support an open-forest of *Eucalyptus beyeri, E. punctata* and *E. oblonga* with the shrubs *Bursaria longisepala, Daviesia ulicifolia, Oxylobium ilicifolium, Indigofera australis, Persoonia linearis* and *Breynia oblongifolia* in the understorey. Groundcover species include *Dianella revoluta, Patersonia sericea, Lomandra longifolia* and *Entolasia stricta.*

The western boundary of the 'Sydney Sandstone Complex' is difficult to define, though it appears to be related to rainfall and minimum temperatures. An altitudinal upper limit of 800 m has been used for physiographic and floristic reasons. The higher country further west is a less dissected landscape with complex pattern of heath, rock outcrops and woodland leading up to the Newnes Plateau. The 800 m contour also approximately separates the 'low elevation species' such as *Angophora costata, Eucalyptus gummifera, E. punctata* and *Syncarpia glomulifera* from the 'high elevation species' such as *E. mannifera* subsp. *gullickii, E. oreades, E. radiata* subsp. *radiata* and *Banksia spinulosa* var. *cunninghamii.*

Map unit 10f – 'Newnes Plateau Woodland'

Woodland: *Eucalyptus sieberi – E. oreades – E. dives*

This community is confined to the Newnes Plateau, north of Clarence. This is the highest part of the upper Blue Mountains (above 1050 m), and this vegetation represents the highest and coldest development of vegetation on the Sydney Basin Triassic sediments. Here the sandstone is friable and weathers to a deep, well-drained soil with a moderate clay content (Pecover 1984). Although characterized as woodland, the vegetation includes a range of structural formations from open-forest through woodland to open-woodland and occasionally to low woodland. Structural variation is due to both natural environmental factors, and management treatments, mainly selective logging which has been mostly concentrated in the taller open-forests and woodlands.

The dominant tree species vary considerably. Though some local 'forest types' reflecting local topographic or soil factors could be recognized, these could not be mapped consistently from the aerial photography. The most common tree species are *Eucalyptus sieberi, E. oreades, E. radiata* subsp. *radiata* and *E. dives. Eucalyptus blaxlandii* and *E. dalrympleana* subsp. *dalrympleana* are found in more sheltered situations, while *E. mannifera* subsp. *gullickii* and *E. pauciflora* occur on cold, poorly-drained sites. *Eucalyptus oreades* is notable as the only 'fire sensitive' eucalypt in the area. Adult trees are generally killed by severe fire, which provides conditions for regrowth of seedlings (Glasby et al. 1988). Young trees in Newnes State Forest are a major source of pit-props. Other eucalypt species here resprout from epicormic buds or lignotubers after fire.

The understorey is generally an open shrub layer 1 to 2 m high with an intermittent grassy ground cover. Common shrub species are *Acacia dorothea, A. terminalis, Daviesia latifolia, Boronia microphylla, Mirbelia platyloboides, Phyllota squarrosa, Monotoca scoparia, Hibbertia obtusifolia, Leptospermum squarrosum, Persoonia laurina, Lomatia silaifolia, Hakea dactyloides* (multi-stemmed form) and *Petrophile canescens.* Juveniles and saplings of the *Eucalyptus* canopy species are frequently common, particularly where there has been logging.

Common ground plants are *Lomandra multiflora, L. glauca, Dianella revoluta, Lepyrodia scariosa* and the grasses *Stipa pubescens, Chionochloa pallida* and *Poa labillardieri.* Spreading prostrate shrubs are conspicuous, particularly *Grevillea laurifolia* and *Persoonia chamaepitys.* These appear to be colonizers and are found along roadsides and where the canopy has been removed. The rare *Isopogon prostratus,* a prostrate species closely related to the common *Isopogon anemonifolius,* occurs in small populations in Newnes State Forest.

This species had formerly been recorded from Clarence but had been destroyed by sand quarrying. The nearest known locality is Fitzroy Falls, near Robertson. It has also been recorded from a few isolated localities in the Southern Tablelands, the South Coast and Victoria. Much of the 'Newnes Plateau Woodland' has been cleared for *Pinus radiata* plantations, and most of the remainder is within State Forest and regularly logged.

Map unit 10g – 'Scribbly Gum – Stringybark Woodland'

Woodland: *Eucalyptus rossii – E. oblonga*

On the drier western aspects of the Triassic sandstone plateau and extending onto Permian sandstones further west is woodland with *Eucalyptus rossii* (Scribbly Gum) and *E. oblonga* (Stringbark). It is particularly common in Ben Bullen State Forest. Rainfall is less than 900 mm p.a and generally, this vegetation occurs on upper ridge slopes where soils are dry, shallow, infertile sandy loams. *Eucalyptus sieberi* and *E. piperita* may be found around sandstone outcrops and in small gullies, where soils are slightly deeper and better-drained. Southerly aspects may have *E. macrorhyncha.*

On the sandstone plateau the understorey is shrubby with *Oxylobium ilicifolium, Acacia buxifolia, A. terminalis, Boronia microphylla, Dillwynia phylicoides, Monotoca scoparia, Leucopogon muticus, Brachyloma daphnoides* and *Persoonia linearis.* Groundcover species include *Chionochloa pallida, Lomandra multiflora, L. glauca, Pseudognaphalium luteo-album* and *Dianella revoluta.* Where *E. rossii* and *E. oblonga* extend onto Permian sediments this unit intergrades with the 'Tablelands Grassy Woodland Complex' (map unit 10h), and grasses predominate in the understorey, particularly *Chionochloa pallida* but also with *Agrostis avenacea, Dichelachne rara, Echinopogon ovatus, Poa sieberiana* and *Stipa* species.

Map unit 10h – 'Tablelands Grassy Woodland Complex'

Woodland: *Eucalyptus rossii – E. macrorhyncha*

Woodland: *E. mannifera – E. dives*

Open-forest: *E. dalrympleana*

Woodland: *E. pauciflora – E. rubida*

This map unit includes a number of communities characteristic of the poorer soils of the Tablelands. It is found on soils derived from Permian shales, conglomerates and sandstones along the western edge of the map sheet from Wallerawang north to Ben Bullen. Soils are yellow, hardsetting, texture-contrast, sandy loam soils (Hamilton 1976).

Species groupings appear to be strongly related to topographic position. On hilly sites, particularly on dry, northern to western aspects, is woodland with *Eucalyptus rossii, E. macrorhyncha* and less commonly *E. mannifera* subsp. *mannifera.* The understorey is open with scattered grasses and occasional shrubs, the amount of cover depending on season and rainfall conditions. The most common grasses include *Chionochloa pallida, Danthonia laevis, Poa sieberiana, P. labillardieri* and *Agrostis avenacea.* Other groundlayer species include *Lomandra multiflora, Dianella laevis, Stylidium graminifolium* and

Gonocarpus tetragynus. There may be shrubs of *Acacia buxifolia, Brachyloma daphnoides, Lissanthe strigosa* and *Hibbertia obtusifolia.* This vegetation often grades into the Scribbly Gum – Stringybark Woodland (map unit 10g) on adjacent sandstone ridges.

Woodland with *Eucalyptus mannifera* subsp. *mannifera* and *E. dives* occurs on country of lower relief. The understorey composition here is similar to that associated with *E. rossii*, but ground cover may be more dense. On lower slopes with more shelter and deeper colluvial or alluvial soils is open-forest of *E. dalrympleana* subsp. *dalrympleana*, sometimes with *E. bridgesiana* or *E. viminalis*, the latter particularly along creeklines. These forests usually contain one or more tall shrub/small tree layers, commonly with *Acacia dealbata, A. obliquinervia, Leptospermum flavescens* and *Eucalyptus* sapling regeneration. Ground cover may be 60–80%, with herbaceous species such as *Dichondra repens, Gonocarpus tetragynus, Acaena nova-zelandiae, Viola betonicifolia, Glycine clandestina* or frequently may be dominated completely by *Pteridium esculentum* possibly resulting from frequent burning.

Woodland of *E. pauciflora* and *E. rubida* may be found in cold air drainage hollows on undulating to flat country. The relatively uncommon species *E. aggregata* also occurs here, generally associated with creek lines. The understorey is generally heavily disturbed, though remnant species may include *Themeda australis, Sorghum leiocladum, Asperula conferta, Hypoxis hygrometrica* and *Desmodium varians.* This community appears to have been particularly common from Blackmans Flat to Wallerawang but has now been largely cleared.

Map unit 10i – 'Talus-slope Woodland'

Woodland: *Eucalyptus rossii – E. macrorhyncha – E. polyanthemos – E. fibrosa*

Open-forest: *E. cypellocarpa – E. eugenioides – E. punctata – E. melliodora*

The slopes below the major cliff-lines that form the western escarpments of the Triassic sandstone plateaus are composed of strata of the Permian Illawarra Coal Measures together with sandstone blocks and scree material from the Narrabeen Group cliffs above. Soils are Hamilton's (1976) yellow, hardsetting, texture-contrast, sandy loams.

Vegetation structure and floristics vary with exposure and rainfall. Exposed dry slopes have woodland with *Eucalyptus rossii, E. macrorhyncha, E. polyanthemos* and *E. fibrosa.* This vegetation is common in the Capertee Valley, which probably receives less rainfall than the Wolgan Valley further south. Escarpment slopes around Lithgow receive the highest rainfall and support 'Montane Gully Forest' (map unit 9j). More sheltered slopes, particularly the lower slopes, have open-forest with *E. cypellocarpa, E. eugenioides, E. punctata,* and *E. melliodora.* Less common trees include *E. crebra, E. blakelyi, E. tereticornis* and *Angophora floribunda,* while *E. piperita* subsp. *piperita* often intrudes onto the upper slopes from the plateau above. *Eucalyptus dawsonii* and *E. sideroxylon* are species of more localised occurrence here, found on lower slopes near Glen Davis.

The understorey is generally open, with scattered shrubs including *Isopogon dawsonii, Acacia obtusifolia, A. falciformis, Allocasuarina littoralis, Correa reflexa, Daviesia ulicifolia, Dillwynia acicularis, Dodonaea triquetra, D. viscosa,* *Leptomeria acida, Leptospermum flavescens, Leucopogon muticus, Lissanthe strigosa, Persoonia linearis* and *Prostanthera ovalifolia.* Ground cover depends on exposure and ranges from scattered clumps of grass on bare, rocky hillsides to a herbaceous ground layer on more sheltered sites. Ground species include *Ajuga australis, Plantago debilis, Lomandra longifolia, Dichondra repens, Desmodium varians, Wahlenbergia stricta* subsp. *stricta* and *Dianella revoluta.*

Along banks and small flats associated with the Wolgan River is open-forest of *Eucalyptus viminalis, E. eugenioides, E. blakelyi* and occasionally *E. cypellocarpa. Casuarina cunninghamiana* lines the water's edge. Small trees of *Acacia filicifolia* are common on the river flats, many of which were cleared many years ago for grazing or for the Newnes shale oil complex. Ground cover consists of small shrubs of *Dodonaea triquetra, Indigofera australis, Breynia oblongifolia* and ground plants, *Pteridium esculentum, Pellaea falcata, Viola hederacea* and *Doodia aspera.* Similar vegetation is found along the Capertee River below Glen Davis.

Map unit 10j – 'Capertee Valley Woodland'

Woodland: *Eucalyptus melliodora – E. blakelyi*

Woodland: *E. fibrosa – E. crebra*

The floor of the Capertee valley has yellow, hardsetting, texture-contrast sandy loams developed from Permian shale, sandstone and conglomerate sediments (Hamilton 1976). The valley is within a rain-shadow and rainfall may be as low as 600 mm p.a. Though now generally cleared, there was originally woodland here similar to that of the south-eastern temperate woodlands of the Western Slopes described by Moore (1970). Tree species include *Eucalyptus melliodora* and *E. blakelyi* on flats and in depressions, and *E. albens, E. crebra* and *Brachychiton populneus* on rises. There are occasional stands of *E. microcarpa, E. conica, E. sideroxylon* and *E. parramattensis.* The understorey was originally grassy and has been heavily grazed.

At the western end of the Capertee Valley is a plateau at 500–600 m elevation, forming the foothills of the outlying Narrabeen sandstone mesas – Airly and Genowlan Mountains, and Pantoneys Crown (Figure 4). This has leached yellow gradational sandy loam soils which support woodland with extensive areas of the ironbarks, *Eucalyptus fibrosa* subsp. *fibrosa* and *E. crebra.* The Black Cypress Pine, *Callitris endlicheri* is particularly conspicuous. Tree species associated with the adjacent 'Talus-slope Woodland' (map unit 10i) including *E. macrorhyncha, E. rossii, E. polyanthemos, E. oblonga, E. cannonii* and *E. goniocalyx* may also be found. The understorey is open with scattered shrubs such as *Dodonaea viscosa, Astroloma humifusum* and *Acrotriche serrulata,* and ground plants such as *Dianella revoluta, Dichelachne micrantha, Echinopogon ovatus, Lepidosperma laterale, Bossiaea buxifolia* and *Lomandra glauca.*

Map unit 10k – 'White Box Woodland'

Woodland: *Eucalyptus albens – Brachychiton populneus*

Woodland: *Angophora floribunda – E. melliodora*

In the dry northwest corner of the map sheet the gorges of Airly, Coco and

Genowlan Creeks, and the upper Capertee River cut deeply into Devonian shales, siltstones, quartzites, tuffs and limestone (Figure 5). Here, are steep slopes with yellow, leached, gradational, loamy soils, with a woodland, 15–20 m high, of trees of *Eucalyptus albens* and occasionally *Brachychiton populneus.* The understorey is sparse (about 20% cover) with the grasses *Aristida vagans, Poa sieberiana, Themeda australis* and herbs *Desmodium brachypodum, Ajuga australis, Plantago debilis* and *Asperula conferta.* There are occasional shrubs of *Acacia implexa, Acacia falciformis, Pimelea hirsuta, Bursaria spinosa, Notelaea microcarpa* and *Indigofera australis.*

Dense populations of *Xanthorrhoea glauca* subsp. *angustifolia* up to 4 m tall are a conspicuous feature of some spurs and ranges on Devonian geology, particularly in the southern Capertee Valley near Crown Creek. These are associated with populations of the characteristic inland grass *Triodia irritans* var. *laxispicata*, which appears to be a relict of a once more continuous distribution in the Pleistocene Period (Jacobs 1982). Other grasses *Cymbopogon refractus, Dichanthium sericeum, Themeda australis, Aristida vagans, A. ramosa* and *Stipa* sp. There are occasional shrubs of *Acacia decora.*

Alluvial areas associated with this community may have trees of *Eucalyptus melliodora, E. tereticornis, Angophora floribunda* and less commonly *E. viminalis.* Ground cover is generally dense (90%) with *Pteridium esculentum, Hydrocotyle laxiflora, Dichondra repens, Echinopogon ovatus, Lomandra*

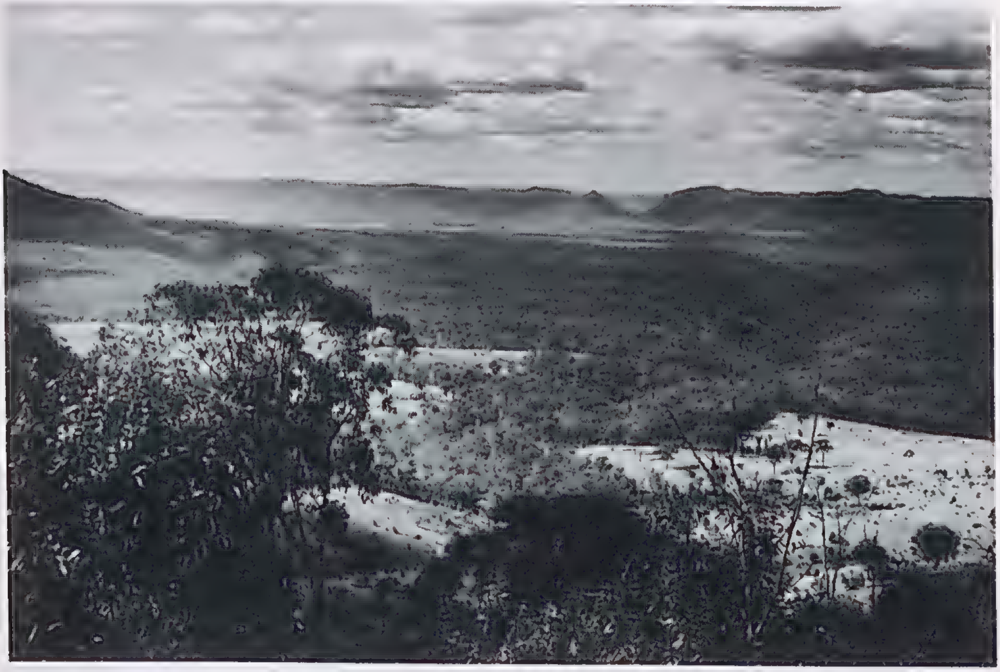

Figure 4. View to east of Capertee Valley from Pearsons Lookout showing Capertee Valley woodland (map unit 10j) with *E. fibrosa* and *E. crebra* in centre foreground. On right is incised gorge of Airly Creek with *E. albens* White Box Woodland (map unit 10k), while on left are lower slopes of Airly Mountain. In background is sandstone plateau with Talus-slope Woodland on margins (map unit 10i). Capertee River gorge and Glen Davis are in background centre. Compare with 1868 view on map sheet.

longifolia and *Rumex brownii.* The exotic species, *Cirsium vulgare, Echium plantagineum* and *Conium maculatum* are common.

Map unit 10m – 'Mount Walker Complex'

Woodland: *Eucalyptus dives – E. mannifera – E. bridgesiana – E. rossii*

West of Lithgow is an island of rugged country between 1000 and 1100 m elevation, bisected by the Coxs River. Hillsides are very steep with shallow, yellow, well-drained, hardsetting sandy loams derived from Devonian Lambie Group quartzites, sandstones, siltstones and claystones. Vegetation structure is mainly woodland (canopy cover ranges from 10 – 30%), and tree height ranges from 8 to 25 m depending on position (Benson & Keith 1985). *Eucalyptus dives* and *E. mannifera* subsp. *praecox* are the most common trees. *Eucalyptus bridgesiana* is frequent on the lower slopes. *Eucalyptus rossii* may be found occasionally on ridges though it is more common in drier country west of Coxs River.

The understorey has an open shrub layer with *Lissanthe strigosa, Bursaria spinosa, Hibbertia obtusifolia, Acacia falciformis, Dillwynia phylicoides* and *Persoonia linearis.* The groundcover is mid-dense with various grasses *Chionochloa pallida, Danthonia tenuior, Poa labillardieri, Themeda australis* and the introduced *Anthoxanthum odoratum;* herbs including *Poranthera microphylla, Gonocarpus tetragynus, Hypericum gramineum* and *Dianella revoluta,* and twiners *Glycine clandestina* and *Hardenbergia violacea.* A bank of alluvium associated with the Coxs River supports *Eucalyptus viminalis* and a

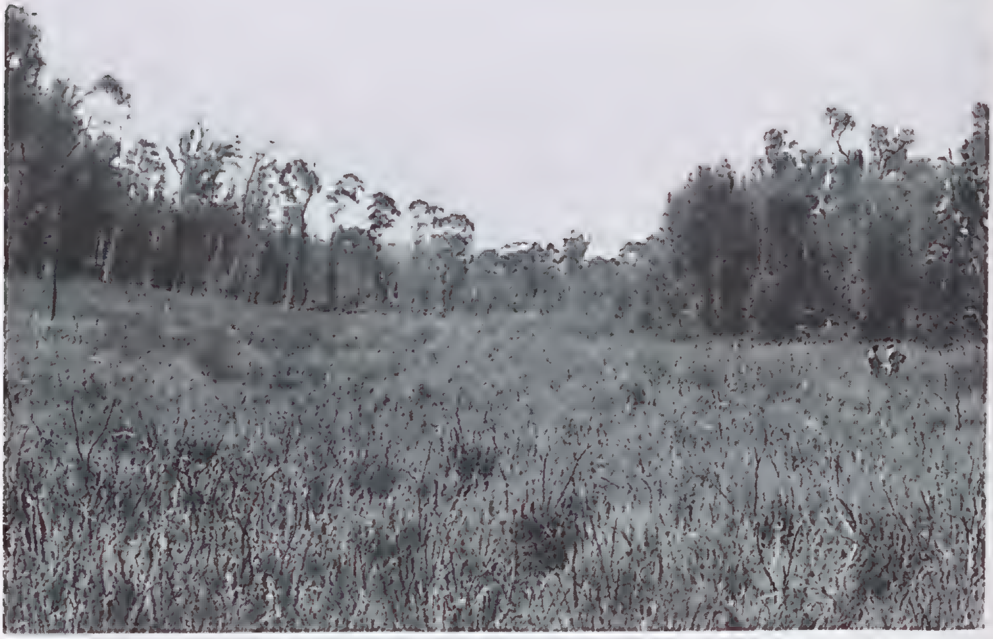

Figure 5. Looking upstream across large shrub swamp on Newnes Plateau (map unit 20a). Swamp and adjacent forest here have been burnt by wildfire about 2 years previously and both trees and shrubs are resprouting vigorously.

scrub of *Callistemon paludosus* and species of *Leptospermum.* On the upper exposed slopes of Mount Walker itself (1187 m) is woodland of *Eucalyptus pauciflora* with *E. mannifera* subsp. *praecox,* an understorey of scattered shrubs of *Persoonia linearis, Leucopogon lanceolatus* and *Lomatia myricoides* and groundcover of *Lomandra longifolia, Stellaria pungens, Stylidium graminifolium* and *Poa labillardieri.* Too small to be mapped here, it is an outlier of the *E. pauciflora* 'Snow Gum Woodland' (map unit 10l on the adjoining Katoomba 1:100 000 map sheet of Keith & Benson 1988). Below this, on the moist, southerly aspect of Mount Walker is open-forest of *E. fastigata* and *E. viminalis.* Here the understorey is mesic with occasional shrubs of *Acacia melanoxylon* and *Rubus parvifolius* and a dense ground cover of ferns including *Polystichum proliferum, Blechnum nudum* and *Pteridium esculentum,* and herbs such as *Geranium potentilloides, Epilobium billardieranum* subsp. *cinereum, Wahlenbergia stricta* subsp. *stricta, Senecio hispidulus, Hydrocotyle acutiloba* (sens. lat.), *Stellaria pungens, Lomandra longifolia* and *Carex appressa.* This is an outlier of the 'Montane Moist Forest', open-forest of *E. fastigata – E. dalrympleana – E. viminalis* (map unit 9n on the Katoomba map sheet). An outlier of the 'Mount Walker Complex' is found south of Hartley on the Katoomba map (Keith & Benson 1988) though the main trees there are *Eucalyptus macrorhyncha* and *E. melliodora.*

In small rocky places *Eucalyptus sieberi* may be found with *E. rossii* and a shrubby understorey. The main species include *Leptospermum flavescens, Oxylobium ilicifolium, Dillwynia phylicoides, Daviesia virgata, Hibbertia obtusifolia, Platysace lanceolata, Brachyloma daphnoides, Leucopogon virgatus, Monotoca scoparia, Persoonia linearis* and *Hakea dactyloides.*

Map unit 10n – 'Dry Basalt Cap Woodland'

Woodland: *Eucalyptus polyanthemos – E. macrorhyncha*

This community is confined to basalt caps on the western sandstone mesas of Airly and Genowlan Mountains. These caps are of very limited extent and weather to a stony, though high nutrient clay soil. Because of the low rainfall (probably less than 800 mm), these support woodland vegetation in contrast to the tall open-forests on the higher rainfall basalt caps further east (map unit 6g). Tree species are *Eucalyptus polyanthemos* and *E. macrorhyncha.* The ground cover is mainly herbaceous with *Hydrocotyle laxiflora, Stellaria pungens, Viola betonicifolia, Ajuga australis, Desmodium varians, Plantago debile, Geranium potentilloides, Urtica incisa, Veronica plebeia, Dichondra repens* and *Cheilanthes sieberi.* There are occasional shrubs of *Melichrus urceolatus, Bursaria longisepala, Cassinia uncata* and patches of *Indigofera australis.* This vegetation occupies an intermediate position on a sequence of basalt soil sites along a rainfall gradient between the high rainfall tall open-forest and rainforest sites at Mount Wilson (Keith & Benson 1988) and the low rainfall (500–600 mm p.a.) open woodland sites on the Merriwa Plains (McRae & Cooper 1985).

Map unit 11a – 'Open Mottled Gum Woodland'

Open-woodland: *Eucalyptus mannifera – E. dives – E. pauciflora*

Open-woodland is found in the poorly-drained basins of creeks on the Newnes Plateau, particularly on the eastern half. It is generally associated with treeless shrub- or sedge-swamps (map unit 20a). Mottled Gum, *Eucalyptus mannifera* (mostly subsp. *gullickii* though there are intergrades with subsp. *mannifera*) is the most common tree species though *E. radiata* subsp. *radiata, E. dives* and *E. dalrympleana* subsp. *dalrympleana* may also be present. *Eucalyptus pauciflora* subsp. *pauciflora* is common on the southern part on the plateau, above about 1170 m altitude.

The understorey is generally open, but with patches of locally denser scrub. The most common shrubs include *Leptospermum flavescens, L. myrtifolium, L. juniperinum, Hakea dactyloides, Lomatia silaifolia, Phyllota squarrosa* and *Boronia microphylla.* The open ground cover consists of *Helichrysum scorpioides, Dianella revoluta, Lomandra longifolia, Gahnia filifolia* and *Lepyrodia scariosa.*

Map unit 20a – 'Newnes Plateau Shrub-Swamps'

Closed-heath: *Leptospermum grandifolium – Baeckea linifolia – Grevillea acanthifolia*

Sedgeland: *Gymnoschoenus sphaerocephalus – Xyris ustulata*

Narrow, elongate, shrub-swamps are a conspicuous feature of the eastern half of the Newnes Plateau. These swamps are formed in characteristic low-slope headwater valleys, mostly tributaries of Carne Creek where sandy organic sediments are deposited from the surrounding ridges. These sediments are relatively deep, with a high organic matter content and sandy or loamy texture, and are periodically waterlogged. The swamp vegetation is essentially dominated by shrubs and varies in structure from open-scrub to closed-heath, with sedgeland dominated by graminoids in very wet sections. There is a considerable variation in the floristic composition, which is probably related to the soil type and the extent and duration of waterlogging. Soils on the western part of the plateau appear to have more clay than those of the eastern part, which are more sandy, while in each swamp the floristic composition is related to a drainage gradient from occasionally flooded sites to almost permanently running water. Trees are normally absent though there is generally a fringing open-woodland of *Eucalyptus mannifera* subsp. *mannifera* and occasionally the Mallee Snow Gum, *E. gregsoniana.* Dead trees in some swamps appear to indicate fluctuations in drainage conditions.

The most extensive plant community is dominated by shrubs, *Epacris paludosa, E. microphylla, Grevillea acanthifolia* subsp. *acanthifolia, Leptospermum grandifolium* (previously included with *L. lanigerum*), *Baeckea linifolia, B. utilis* and *Boronia deanei* with graminoids such as *Restio australis, Lepyrodia scariosa, Empodisma minus, Lepidosperma limicola, Xyris ustulata* and *Patersonia fragilis.* Local patterns appear to relate to drainage. Dense vegetation along permanent water channels within the swamp is dominated by *Gleichenia dicarpa* and *Gymnoschoenus sphaerocephalus* (Figure 5). In the drier, more open areas, there is an herbaceous ground cover with *Hydrocotyle* sp., *Viola hederacea* subsp. *sieberiana, Gonocarpus tetragynus* and *Xanthosia dissecta.*

In the swamps with a higher clay content, *Leptospermum* species are increasingly important, particularly *Leptospermum flavescens, L. myrtifolium, L. continentale* J. Thompson, and *L. obovatum.* Ground cover often includes *Restio australis, Juncus continuus* and *Lomandra longifolia.*

Periodic fire plays a part in modifying the structure of the shrub-swamp vegetation. After hot burns that kill all above ground vegetation, the sedges and smaller shrubs grow quickly in the increased light, to form a sedgeland, 0.3–0.5 m high. Some of the interesting locally restricted small shrub species such as *Boronia deanei, Dillwynia stipulifera* and *Celmisia* sp. aff. *longifolia* are conspicuous at this stage. The sedgeland is gradually overtopped by the taller growing shrubs, which gradually form a dense canopy about 2–3 m high.

The orientation of these swamps relate to the Deanes Creek Lineament and the Happy Valley Lineament which dominate the hydrology in the central part of the Newnes Plateau (Pecover 1984). The orientation of these swamps (NNE–SSW) contrasts markedly with the deeply incised easterly drainage pattern developed throughout much of the Blue Mountains and Wollemi National Parks and suggests a paleo-drainage pattern on the Newnes Plateau that is considerably older than drainage regimes that have formed many of the deeply incised valleys of the western Blue Mountains. Pecover (1984) suggests that the present land surface of the Newnes Plateau may be at or near the position of a paleo-land surface of Tertiary age or older.

Map unit 20b – 'Coxs River Swamps'

Closed-heath: *Leptospermum obovatum – Leptospermum continentale*

Sedgeland: *Carex* species

Alluvium-filled swamps near Ben Bullen along tributary creeks of the Turon River, and along the upper Coxs River and its tributaries north of Lidsdale are more clayey and perhaps have a higher nutrient status than the Newnes Plateau Shrub Swamps (map unit 20a). In more waterlogged areas there is closed-sedgeland of *Carex gaudichaudiana* and *C. fascicularis,* with herbs including *Viola caleyana, Stellaria angustifolia, Hydrocotyle tripartita, Mitrasacme serpyllifolia, Epilobium billardieranum* subsp. *hygrophyllum, Utricularia dichotoma,* and grasses including *Poa labillardieri* and *Deyeuxia quadriseta.* Sphagnum may be present. In other sites may be closed-heath with *Leptospermum obovatum, L. continentale* and *L. flavescens. Restio australis* and *Baeckea utilis* may be associated with more localized sandy textured soils. Drier areas carry *Poa labillardieri* grassland, occasionally with a light shrub cover of *Leptospermum continentale.* Open-forest of *Eucalyptus viminalis* and *E. dalrympleana* subsp. *dalrympleana* often surrounds these swamps.

Rather similar swamps are found at Hartley Vale and below Nellies Glen on the Katoomba map (Keith & Benson 1988).

Map unit 21c – 'Montane Heath'

Open-heath: *Allocasuarina nana – Banksia ericifolia – Leptospermum attenuatum – Phyllota squarrosa*

Spectacular areas of open-heath are found at high elevations (above 850 m) (Figure 6), mainly on the southern half of the Newnes Plateau, particularly to the north of Lithgow. Heath occupies exposed ridgetops with skeletal sandy soils derived from Narrabeen Group sandstones. Major shrub species are *Allocasuarina nana, Leptospermum attenuatum, L. arachnoides, Isopogon anemonifolius, Banksia ericifolia* var. *ericifolia, Hakea dactyloides* (multistemmed form), *H. propinqua, Brachyloma daphnoides, Epacris microphylla,* and *Monotoca scoparia.* Species restricted to high elevations include *Acacia gunnii, A. dorothea, Mirbelia platyloboides, Phyllota squarrosa, Pultenaea canescens, Petrophile canescens, Boronia microphylla* and *Eriostemon obovalis.* Localized patches of mallee eucalypts, *Eucalyptus* sp. nov. 'MOKII' or *E. stricta* may be present, though *E. stricta*, found only on the southern half of the plateau, is more common in Montane Heath on the Katoomba map (Keith & Benson 1988). *Eucalyptus gregsoniana*, another mallee, and *E. mannifera* subsp. *gullickii*, a small tree, are less common and restricted to higher elevations.

Sedges and forbs make up the ground cover. The most common species include *Gahnia filifolia, G. microstachya, Lepidosperma viscidum, Schoenus villosus, Chionochloa pallida, Patersonia longifolia, Dampiera stricta* and *Goodenia bellidifolia.* In sites with very shallow soil, or poor drainage, shrubs are less frequent and expanses of sedgeland predominate. *Lepidosperma viscidum* may be particularly common on exposed rocky sites.

Map unit 21d – 'Pagoda Rock Complex'

Open-heath: *Allocasuarina nana – Leptospermum arachnoides – Lepidosperma viscidum*

Open-scrub: *Eucalyptus* sp. nov. 'MOKII'

Woodland: *E. piperita – E. rossii*

Along the escarpments on the margins of the Triassic sandstone plateaus are exposed sandstone cliffs, ridges and rocky outcrops, frequently weathered to large, rocky and scenically very striking domes, often of a characteristic 'pagoda' or beehive shape. Vegetation structure on these escarpments ranges from open-forest to woodland, low woodland, open-scrub and open-heath, depending on the extent, shape and exposure of outcropping sandstone. In the sheltered sites there is open-forest of *Eucalyptus piperita* subsp. *piperita, E. sieberi* and *E. oblonga* (intrusions from the 'Sandstone Plateau Forest', map unit 9i). With increasing exposure, *E. rossii* and *E. punctata* become common, while around the exposed rocky outcrops and among the 'pagodas' are mallees of *E.* sp. nov. 'MOKII' with *E. oreades* and *E. rossii* (Figure 6).

Understorey species of the forests and woodlands are mostly sclerophyllous shrubs, similar to those of the Blue Mountains Sandstone Plateau Forest (map unit 9i). Common species include *Acacia terminalis, A. ulicifolia, A. obtusifolia, Banksia ericifolia, Calytrix tetragona, Phyllota phylicoides, Platysace lanceolata, Boronia microphylla, Isopogon dawsonii, Allocasuarina distyla, Hakea dactyloides* and *Leptospermum sphaerocarpum.* Patches of 'Montane Heath' (map unit 21c) are associated with the most exposed, rocky sites, though in the northern part of the map sheet area, some of the higher elevation species may be absent.

Discussion

Vegetation patterns

The influences of geology, physiography, elevation and rainfall are evident in

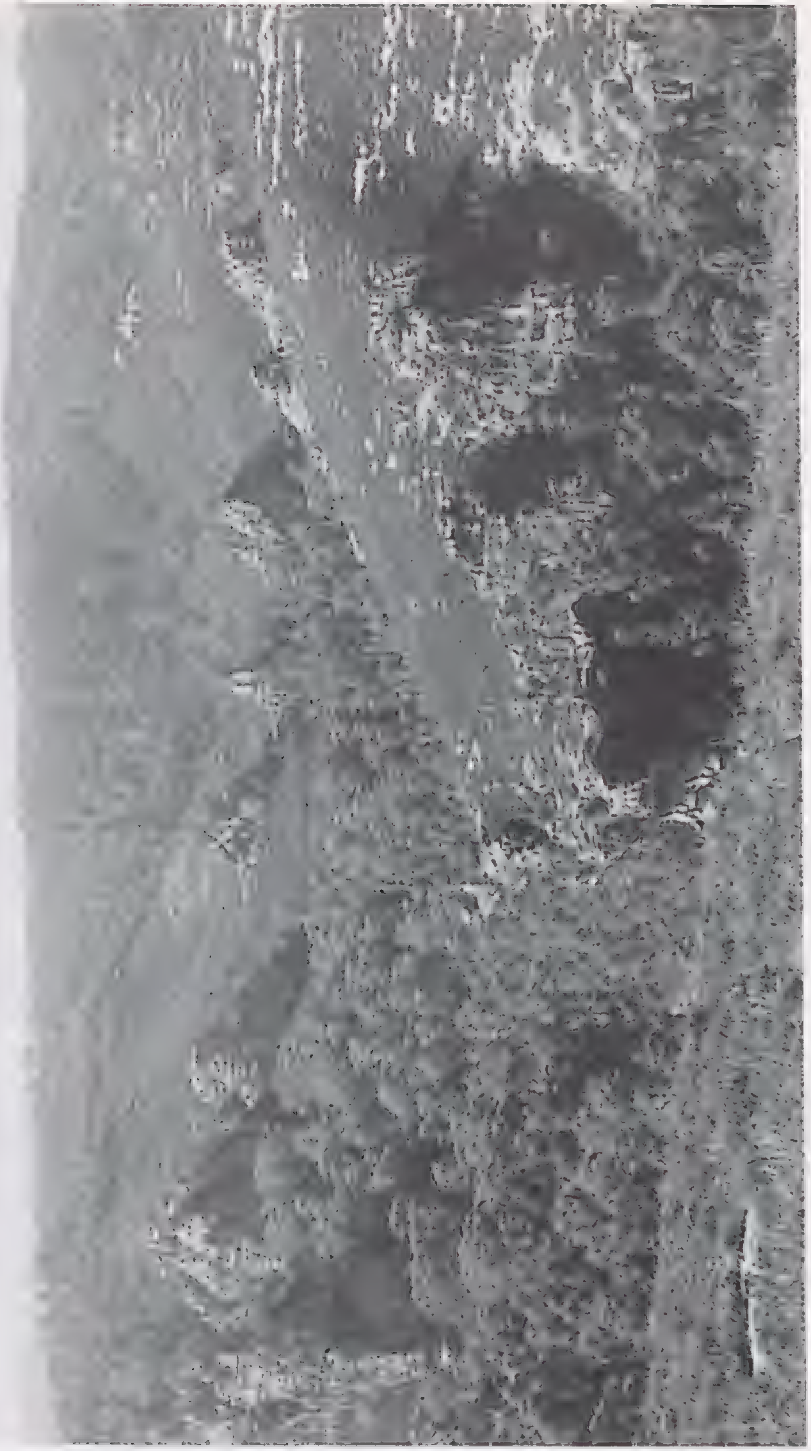

Figure 6. Extensive slopes of recently burnt Montane Heath, and Pagoda Rock Complex (map units 21c & 21d). Valley on left has Montane Gully Forest with *Eucalyptus fastigata* and *E. cypellocarpa* (map unit 9j) while skyline shows Newnes Plateau Woodland of *E. sieberi-E. oreades* (map unit 10f). Site is on Newnes Plateau just north of Lithgow.

the vegetation patterns recognised on the Wallerawang map sheet. Of these geology is probably the most important. Particular geological units are associated with most of the plant communities recognized, a similar situation to other parts of the Sydney Basin, particularly near the coast (e.g. Pidgeon 1937, Benson & Fallding 1981; McRae & Cooper 1985). This association appears to be a response to the texture and nutrient status of the soils. In particular, Beadle (1954, 1962) related the distribution of major vegetation formations to levels of soil phosphorus; from rainforest vegetation associated with high soil phosphorus to sclerophyll heath and woodland associated with very low levels.

On the Wallerawang map sheet, soil types can be divided into two major soil groupings: those with a sandy texture, very low in nutrients and derived from Triassic sandstones; and those with a higher clay content, principally the clay-loams weathered from sedimentary and metamorphic rocks of Permian and Devonian age and from Tertiary and Jurassic igneous rocks. The distinctiveness of these groups is well illustrated by the distributions of the main tree species. Of the 35 eucalypt and related tree species associated with the two major soil groupings (Table 2) 29 species are largely confined to one group of sediments. Of those confined to the Triassic sediments, 9 of the 12 species belong to the eucalypt subgenus *Monocalyptus* (Pryor & Johnson 1971) while 12 of the 17 on Permian sediments belong to subgenus *Symphyomyrtus.* In this area, as well as elsewhere, the predominance of a particular subgenus relates to differences in the nutrient content of the soils (L.A.S. Johnson pers. comm.) *Symphyomyrtus* species are most widespread on fertile soils while *Monocalyptus* species are more common on the least fertile soils. Tree species belonging to the eucalypt subgenus *Corymbia* are here confined to Triassic sandstone, perhaps reflecting a preference for low elevation sites as much as for the low nutrient soils.

Similarly, understorey composition on the two soil groups differs. A diverse sclerophyllous shrub understorey characterises the sandy low-nutrient Triassic

Table 2. Tree species associated with major geological units, with the eucalypt subgenus given in parentheses: *C, Corymbia; M, Monocalyptus; S, Symphyomyrtus.*

Confined mostly to Triassic sediments	**Confined mostly to Permian sediments**	**Found on both Triassic and Permian sediments**
Eucalyptus (C) gummifera	*E. (M) eugenioides*	*E. (M) oblonga*
E. (M) blaxlandii	*E. (M) macrorhyncha*	*E. (M) dives*
E. (M) piperita	*E. (M) rossii*	*E. (M) pauciflora*
E. (M) sieberi	*E. (M) fastigata*	*E. (M) radiata*
E. (M) agglomerata	*E. (S) viminalis*	*E. (S) mannifera*
E. (M) sp. nov. MOKII	*E. (S) dalrympleana*	*E. (S) punctata*
E. (M) sclerophylla	*E. (S) rubida*	
E. (M) oreades	*E. (S) cypellocarpa*	
E. (M) gregsoniana	*E. (S) melliodora*	
E. (M) stricta	*E. (S) fibrosa*	
E. (S) beyeri	*E. (S) crebra*	
Angophora costata	*E. (S) albens*	
	E. (S) blakelyi	
	E. (S) dealbata	
	E. (S) microcarpa	
	E. (S) polyanthemos	
	Angophora floribunda	

soils, typified by the well-known 'Hawkesbury Sandstone flora'. In contrast, grasses, graminoids and herbs characterise the understorey on the more fertile, clayey soils derived from Permian and Devonian sediments and the limited igneous geology.

At higher elevations, differences relating to geology are less clear-cut. Woodlands on some Devonian and Permian sediments above 900 m near Wallerawang have similar tree and shrub species to those on the Triassic sediments, though there appear to be differences amongst the less common species. The Scribbly Gum – Stringybark Woodland (map unit 10g) may occur on either Triassic or Permian geology, though again there are differences in understorey species. Keith & Benson (1988) also noted similar vegetation on different geological groups at high elevations on the Boyd Plateau.

The range of localised physiographic conditions present within some map units results in considerable structural and floristic variation. The best examples of this include Blue Mountains Sandstone Plateau Forest (9i), the Sydney Sandstone Complex (10ag & 10ar), Tablelands Grassy Woodland Complex (10n), Talus-slope Woodland (10i) and the Pagoda Rock Complex (21d). Physiographic influence is evident in the distribution of heath communities (map units 21c & 21d) which relate to particularly exposed situations.

Altitude and climate also have a profound effect on vegetation patterns. The differences between Montane Gully Forest and Talus-slope Woodland (map units 9j & 10i) relate mainly to their different elevations and climates, as they occupy similar geology and topographic positions. The sandstone plateau communities, 10ar-9i-10f, also form an altitudinal sequence from the lower elevation Sydney Sandstone Ridgetop Woodland to the high elevation Newnes Plateau Woodland. Differences in altitude and rainfall appear to have greater effects on communities on clayey or higher nutrient soils than those on sandy soils. For example, there are marked differences between vegetation on high and low rainfall basalt sites (compare units 6g & 10n), but less obvious differences between vegetation on adjacent sandstone (map unit 9i in both cases) growing under similar altitudinal and rainfall conditions.

Management and conservation

Human influences have been concentrated in the valleys on the western side of the map sheet area, where the main impact on the vegetation has been from clearing for agriculture, or on the Newnes Plateau, clearing for *Pinus radiata* plantations. There has also been some disturbance to shrub swamps from siltation and run-off. Also in the native forests on the Plateau, a long history of selective logging for saw logs and pit props, has resulted in a maze of roads and trails, but appears to have caused relatively little floristic change, though vegetation structural change is apparent. Fire frequencies appear to have been generally low, with intervals of 15–20 years between fires, a regime that appears to be suitable to sustain the major plant communities.

The impacts of the various mining and industrial activities have been varied. The industrial complexes at Newnes, Airly and Glen Davis severely disturbed localised sites, but where vegetation has been allowed to regenerate naturally, there has been significant recovery, particularly at Newnes. Currently coal mines are sited along the western edge of the Newnes Plateau, to minimize direct impacts on the Plateau vegetation, but there has been cliffline collapse and damage to 'Pagoda Rock Complex' associated with subsidence from the underground workings.

Major conservation reserves on the Wallerawang map sheet include Wollemi National Park, Blue Mountains National Park, and Pantoneys Crown Nature Reserve (Figure 7, Table 3). These two national parks cover large areas of sandstone on the eastern half of the map sheet, and plant communities widespread in this area (map units 9i, 10ag, 10ar, 10g & 21d) are well conserved. The more restricted communities on the western sandstone plateau are, in general, less adequately treated. An exception is the Moist Basalt Cap Forest (map unit 6g) most of which is included in Wollemi National Park. However, only very small samples of communities in map units 10f, 11a, 20a & 21c are represented in reserves. These typify high elevation sandstone vegetation and, with the exception of the Montane Heath (21c), are restricted to the Newnes Plateau. The Newnes Plateau is already the site of extensive pine plantations and some sand quarries, and has been proposed as a future major source for Sydney's construction sand (Pecover 1984, N.S.W. Dept. of Planning 1990). Action to ensure adequate conservation of these vulnerable plant communities is needed.

Plant communities on the western part of the map sheet associated with Permian and Devonian geology are also very poorly conserved. Forster (1981), in an assessment of conservation values for vegetation in the western coalfields and Upper Hunter, described such forests and woodlands as only moderately to reasonably reserved in Australia. He regarded their conservation suitability in the Wallerawang area as high. Samples of Capertee Valley Woodland and White Box Woodland (map units 10j & 10k), and a small area of Talus-slope Woodland (10i) are included in Pantoneys Crown Nature Reserve. Other woodland communities in the western part of the area (in map units 10h, 10m & 10n), and the Coxs River Swamps (20b) are not represented in any local reserves.

Extensions to Wollemi National Park to include the Mount Airly and

Table 3. Major conservation reserves in the area covered by the Wallerawang 1:100 000 vegetation map sheet.

Reserve	Administered by	Approximate area (ha) on map sheet	Map units included
Blue Mountains National Park	National Parks & Wildlife Service	21,000	9i, 9j, 10ar, 10ag, 11a*, 20a*, 21d
Wollemi National Park	National Parks & Wildlife Service	95,000	6g, 9i, 9j, 10ar, 10ag, 10g, 10i, 11a*, 20a*, 21d
Pantoneys Crown Nature Reserve	National Parks & Wildlife Service	3,230	9i, 10i, 10j, 10k*, 21d
Birds Rock Flora Reserve	Forestry Commission	415	9i, 9j, 10f*, 21c*, 21d

Map units not conserved: 10h, 10m, 10n, 20b.
* represented by small examples only

Genowlan mesas in the Capertee Valley were recommended by Falconer (1986) and would conserve examples of map unit 10n and additional areas of map units 10i, 10j and 10k. A proposal put forward by the National Parks Association in June 1985 to establish a Nature Reserve at Mount Walker would adequately conserve map unit 10m.

Twenty-two plant species of particular conservation significance have been listed for the Wallerawang map sheet (Table 4) though because of the inaccessibility of the area, this is probably an underestimate. Some species, such as *Apatophyllum constablei* and *Rupicola* sp. 1, are highly restricted local endemics, known only from a few localities; while others, locally restricted to particular habitats, have also been recorded in other regions. For example, *Eucalyptus gregsoniana, Boronia deanei* and *Dillwynia stipulifera* are locally restricted to swamps on Newnes Plateau, but have also been recorded from the Budawangs. Other species, such as *Pultenaea incurvata* and *Eriostemon obovalis,* have been recorded elsewhere in the Blue Mountains. Particular concentrations of rare species appear to be on the high elevation Newnes Plateau, and in the Capertee region near Glen Davis, and these areas may represent refugia during periods of climate change. Two very localized species were recently recorded from the Newnes Plateau, *Leptospermum blakelyi* and the first record of what appears to be a new species of *Micromyrtus* (Peter Wilson pers. comm.). These are near the recently notified Snow Gum Forest Preserve No 215 (Forestry Commission of N.S.W. 1989), though the adequacy of the reserve to protect these species is yet to be assessed.

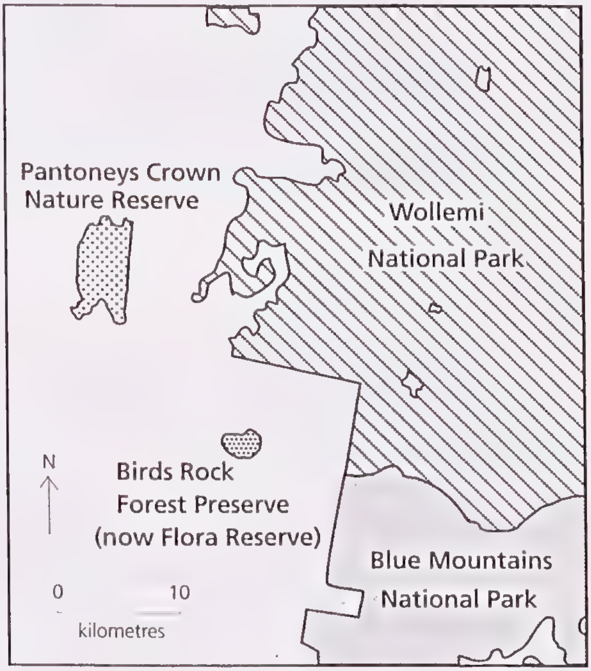

Figure 7. Location of conservation reserves in the area covered by the Wallerawang map sheet.

Table 4. Species of particular conservation significance within the Wallerawang 1:100 000 map sheet area. Species listed here are either rare or threatened (Briggs & Leigh 1988), or of botanical significance in terms of geographic distribution or localised populations disjunct from other occurrences. Localities refer to Wallerawang map sheet occurrences. Nth = northern, Sth = southern, codings are from Briggs & Leigh (1988).

Species (family)	Habitat/Locality	Significance
APIACEAE		
Eryngium vesciculosum	Hartley Vale	Disjunct local population
ASTERACEAE		
Celmisia sp. nov. aff. *longifolia*	Newnes Plateau swamps, Blackheath, Wentworth Falls	Disjunct local population
Olearia quercifolia	Swamps, Clarence to Wentworth Falls	3RC-, local endemic
CELASTRACEAE		
Apatophyllum constablei	Cliff line, Glen Davis	2E, very restricted local endemic
EPACRIDACEAE		
Rupicola sp. 1	Cliffs, Glen Davis	2R, restricted local endemic
FABACEAE		
Acacia asparagoides	Blackheath, Newnes Plateau	2R, local endemic
Acacia kybeanensis	Clarence, Newnes	local disjunct population. Nth-limit
Dillwynia stipulifera	Swamps, Newnes Plateau	3RCi, local disjunct population. Nth-limit
Pultenaea incurvata	Swamps, Newnes Plateau, Mt Wilson, Wentworth Falls	2RCt, local endemic
HALORAGACEAE		
Haloragodendron lucasii	Yarramun Creek, open-forest on creek bank	2KC-, local disjunct population (Orchard 1990)
LAMIACEACE		
Prostanthera cryptandroides	Glen Davis	2VCt, local endemic
MYRTACEAE		
Eucalyptus gregsoniana	Poorly-drained heath Newnes Plateau Clarence–Blackheath	3RCa, local disjunct population
Eucalyptus sp. nov. 'MOKII'	Heath on rock out-crops, Newnes Plateau	3RC-t, local endemic
Darwinia peduncularis	Glen Davis, below cliffs	3RCi, local disjunct population
Leptospermum blakelyi	Hassans Walls, Lithgow Water Supply, heath	2R, local endemic (Benson 1990)
Micromyrtus sp. nov.	Lithgow Water Supply, heath	recently discovered endemic taxon (Peter Wilson pers. comm.)
PROTEACEAE		
Banksia conferta var. *penicillata*	Newnes Plateau	3RC-, local endemic variety

Species (family)	Habitat/Locality	Significance
Grevillea johnsonii	Mount Gundangaroo, Capertee Valley	2RCi, local disjunct population. Sth-limit
Isopogon prostratus	Newnes Plateau	local disjunct population. Nth-limit
Persoonia marginata	Capertee	2V, local endemic
RUTACEAE		
Boronia deanei	Swamps, Newnes Plateau	2VCa, local disjunct population. Nth-limit
Eriostemon obovalis	Newnes Plateau, Blackheath-Bell	3RCa, local endemic
SCROPHULARIACEACE		
Parahebe sp.1	Clarence, Mt Horrible	2RC-, local endemic

The area of the Wallerawang map sheet contains a rich variety of plant communities, but although there are extensive conservation reserves, they conserve only part of the diversity of plant communities and species. Very little of the dry western woodlands on Permian and Devonian geology are included in reserves. More important are the woodlands, heath and swamps on the Newnes Plateau, one of the most elevated sandstone plateaus in Australia and of significant regional conservation importance. Though threatened by a potentially massive sand extraction industry, they remain unprotected.

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SHORT COMMUNICATION

Leptospermum: Rare or threatened species in New South Wales.

Briggs & Leigh (1988) list eleven species of *Leptospermum* as rare or threatened in New South Wales, of which all but *L. epacridoideum* were undescribed at the time. A series of codes were used to distinguish the different taxa. Since then Thompson (1989) has revised the genus and described the new taxa but does not give the codes or provide information on the conservation status of any of the species. In the light of Thompson's study, the present paper seeks to clarify the names and conservation status of the rare taxa listed by Briggs & Leigh for New South Wales, together with one they overlooked (*L. crassifolium*), as well as providing additional information on the distribution and ecology of the species. This information is based on the specimens at the National Herbarium of New South Wales and identified by Thompson; it has not involved any additional field checking.

Symbols used in the conservation code of Briggs & Leigh are as follows; 2 — geographic range < 100 km; 3 — geographic range 100+ km; V — vulnerable; R — rare; K — poorly known; C — population reserved; i — inadequately reserved; — adequacy of reservation unknown.

Leptospermum argenteum *J. Thompson*

Previously sp. 1 Briggs & Leigh (1988).

Distribution: Northern Tablelands; restricted to Barrington Tops, from Tomalla to the Mount Royal Range.

Ecology: Locally abundant along creeks (e.g. Polblue Creek), associated with woodland of *Eucalyptus stellulata* or *E. pauciflora* on basalt soils. Above 1200 m elevation.

Conservation status: coded 2RC – by Briggs & Leigh (1988). Some populations are within Barrington Tops National Park, others within State Forest.

Leptospermum blakelyi *J. Thompson*

Previously sp. 12 Briggs & Leigh (1988).

Distribution: Central Tablelands, known from only two sites within 5 km of Lithgow; Hassans Walls (last collected 1981) and on ridge overlooking Lithgow Water Supply (last collected 1939), population confirmed 1990 (P Hind & R Coveny pers. comm.)

Ecology: occurs in heath on shallow sandy soil, on exposed sandstone escarpments above 1100 m. In Pagoda Rock Complex of Keith & Benson (1988). Above 1100 m elevation. Flowers November–December.

Conservation status: coded 2R by Briggs & Leigh (1988). Not recorded for any proclaimed conservation reserve but may be more common in the immediate area, in appropriate habitats, than collections indicate.

Leptospermum crassifolium *J. Thompson*

DISTRIBUTION: Southern Tablelands; northern Budawang Range — restricted to Mount Corang and south end of Quiltys Mountain. Range about 15 km.

ECOLOGY: locally abundant shrub in open-heath on sandstone and conglomerate ridgetops and plateaus in peaty sand in joints and rock crevices or on seepage slopes. About 800 m elevation. Flowers February and perhaps later.

CONSERVATION STATUS: A very restricted species with all known populations within Morton National Park, this species should be coded as 2RCa sensu Briggs & Leigh (1988).

Leptospermum deanei *J. Thompson*

Previously sp. 15 Briggs & Leigh (1988).

DISTRIBUTION: Central Coast; north of Sydney between Port Jackson and Broken Bay, recorded sporadically along upper Lane Cove River and Devlins Creek, Middle Harbour Creek, Calna Creek and Marramarra Creek.

ECOLOGY: tall shrub, locally common in patches on sandy soils on lower hillsides and along permanent freshwater creeks in Hawkesbury Sandstone areas. Below 100 m elevation. Flowers October–November, mature fruits in December.

CONSERVATION STATUS: coded 2V by Briggs & Leigh (1988), but recorded for Davidson State Recreation Area and Marramarra National Park. Also in Pennant Hills Park and Berowra Valley Bushland Park, both managed by Hornsby Shire Council. Vulnerable to weed invasion through eutrophication and pollution of creeks. Upper catchment disturbance already present in most creeks in which it occurs.

Leptospermum deuense *J. Thompson*

Previously sp. 6 Briggs & Leigh (1988).

DISTRIBUTION: South Coast; confined to rocky ranges between the Deua and Moruya River, about 20 km west of Moruya. Total range about 10 km.

ECOLOGY: on steep rocky ridges and cliff faces in skeletal soil on rhyolite (Comerong Volcanics), locally common shrub in shrub community including *Acacia subtilinervis, Eriostemon trachyphyllus* and *Prostanthera porcata.* Elevation 650 m.

CONSERVATION STATUS: coded 2RCa by Briggs & Leigh (1988) indicating that all known populations are conserved within the Deua National Park.

Leptospermum epacridoideum *Cheel*

DISTRIBUTION: South Coast, around Jervis Bay (Currarong; ACT Territory) and up to 25 km inland (Flat Rock Creek; Yerriyong)

Recent investigations of sandstone areas north of the Shoalhaven River by Kevin Mills of the University of Wollongong have failed to confirm a collection made at Austinmer in 1933.

Ecology: locally common in heathy scrub with species such as *Eucalyptus gummifera, Kunzea ambigua* and *Melaleuca thymifolia,* on shallow sandy soil over sandstone. Altitude less than 200 m.

Conservation status: coded 2RC – by Briggs & Leigh (1988) who indicate that the species is recorded for the Gurumbi and Jervis Bay Nature Reserves and Morton National Park though the extent of the conserved populations is not known.

Leptospermum petraeum *J. Thompson*

Previously sp. 11 Briggs & Leigh (1988).

Distribution: Central Tablelands; known from only two sites; Rocky Top, 5 km west of Kanangra Walls (last collected 1985) and Blackheath (exact location unknown, last collected 1923).

Ecology: in *Eucalyptus stricta* scrub (Montane Heath of Keith & Benson 1988) on a broad, exposed rocky ridgetop with shallow sandy loam, above 1200 m elevation. No details for Blackheath site. Flowers November–April.

Conservation status: coded 2RC – by Briggs & Leigh (1988) indicating that the species has been recorded within Kananga-Boyd National Park, though the extent and size of the population is unknown.

Leptospermum rupicola *J. Thompson*

Previously sp. 2 Briggs & Leigh (1988).

Distribution: Central Tablelands; Glen Davis, upper Blue Mountains Blackheath to Wentworth Falls, Berrima (last collected 1901). Central Coast; Kangaroo Valley (last collected early this century).

Ecology: not common, found at base of sandstone clifflines and bases of caves. Elevational range 500 — 1000 km (no information on Berrima and Kangaroo Valley sites). Flowers March–May and September–October.

Conservation status: coded 3RC – by Briggs & Leigh (1988). A poorly known species, some populations in the upper Blue Mountains are within Blue Mountains National Park but whether the species still survives in the other areas is not known.

Leptospermum sejunctum *J. Thompson*

Previously sp. 14 Briggs & Leigh (1988).

Distribution: Central Coast; South Coast junction; within 3 km of Nowra — only three collections — near Bomaderry Creek Weir (last collected 1989); 'Alum Rock' Bomaderry Creek (last collected 1944) and Flat Rock Creek (on Yalwal Road) (last collected 1981).

Ecology: Locally common on sandy soil over sandstone in scrub and woodland with species such as *Eucalyptus gummifera, E. punctata, Kunzea ambigua, Allocasuarina littoralis* and *Hakea sericea.* Elevation range 15–20m.

Conservation status: coded 2K by Briggs & Leigh (1988) indicating that the taxon was poorly known. As it is apparently restricted to bush remnants very close to Nowra, none of which appear to be conserved, it would appear to be vulnerable if not endangered.

Leptospermum spectabile *J. Thompson*

Previously sp. 5 Briggs & Leigh (1988).

DISTRIBUTION: Central Coast; found only along the Colo River.

ECOLOGY: localised small populations found in sandy alluvium or among boulders on river banks in area subject to flooding, in thickets of *Tristaniopsis laurina* and *Lomatia myricoides.* Elevation less than 140 m.

CONSERVATION STATUS: coded 2RC – by Briggs & Leigh (1988), populations in the upper Colo River are within Wollemi National Park, though their size and condition is unknown. Weed invasion may pose threats in lower parts of the River.

Leptospermum subglabratum *J. Thompson*

Previously sp. 3 Briggs & Leigh (1988).

DISTRIBUTION: Southern Tablelands, Budawang Range from Sallee Creek to Pigeon House Mountain. Also an old specimen (collected 1911) from North Head, Ulladulla (South Coast). Range about 30 km.

ECOLOGY: abundant in sand among rocks and in crevices around edges of plateaus and mesas, but generally not on extensive flat plateaus, nor on slopes below clifflines. Elevation about 750 m. Flowers December–January.

CONSERVATION STATUS: coded 2RC – by Briggs & Leigh (1988) and probably adequately conserved within Morton National Park. Rediscovery of the population at Ulladulla would be interesting.

Leptospermum thompsonii *J. Thompson*

Previously sp. 4 Briggs & Leigh (1988).

DISTRIBUTION: Southern Tablelands; confined to top of Clyde Mountain pass, 30 km north-west of Batemans Bay. Range probably less than 3 km.

ECOLOGY: on top of escarpment in open-forest of *Eucalyptus cypellocarpa* and *E. radiata* along swamp edges or along permanently moist creek banks. Also reported on road verge. Elevation about 750 m.

CONSERVATION STATUS: coded 2V by Briggs & Leigh (1988), not recorded for any conservation area, and vulnerable because of its localised occurrence near a major road.

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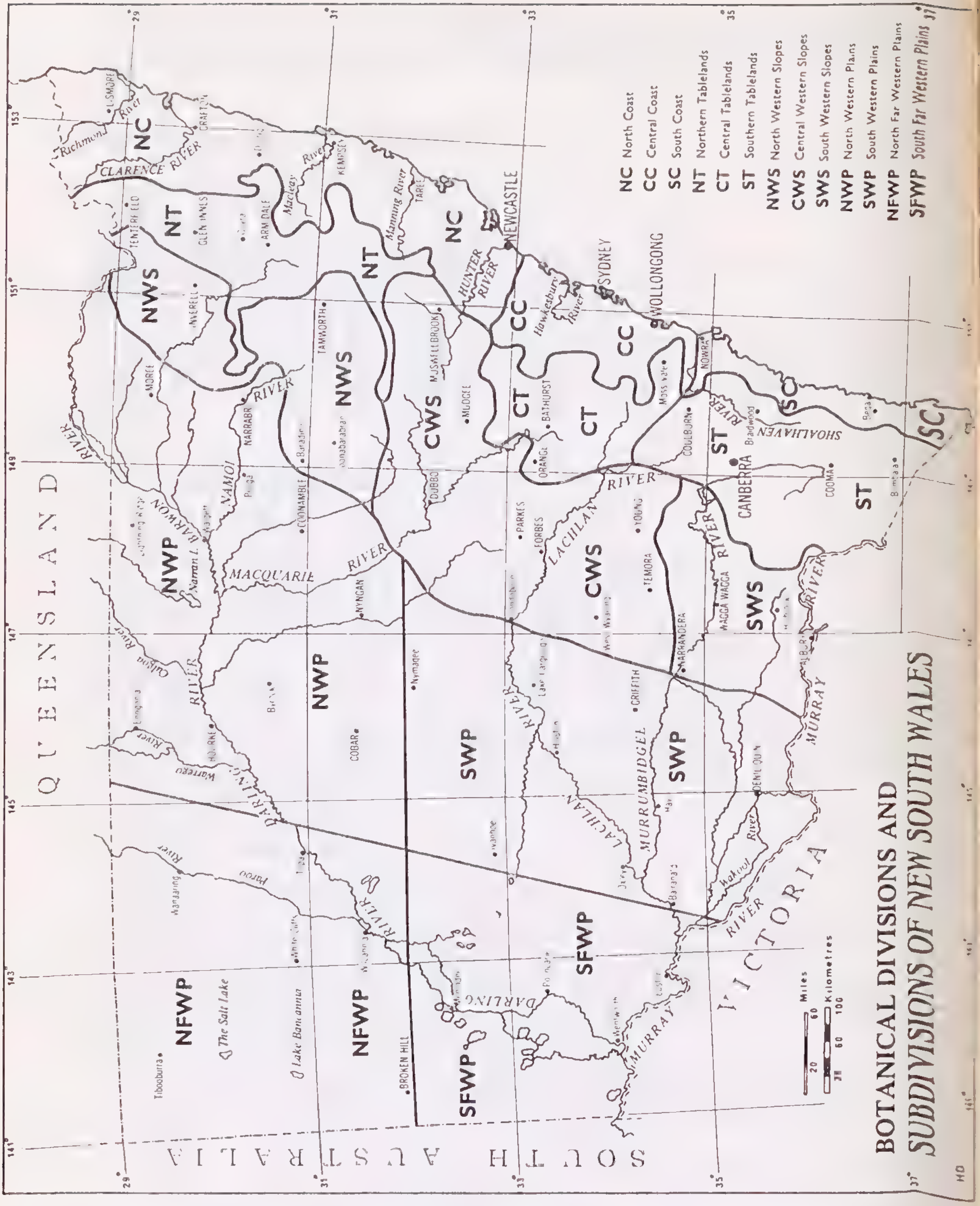

BOTANICAL DIVISIONS AND SUBDIVISIONS OF NEW SOUTH WALES

For explanation and description of the Botanical Divisions and Subdivisions of New South Wales see Anderson, R. H. (1961). Introduction. *Contr. New South Wales Natl. Herb. Fl. New South Wales* Nos 1–18, pp. 1–15.

The effect of 200 years of European settlement on the vegetation and flora of New South Wales

John Benson

Abstract

Benson, J.[*] *(New South Wales National Parks and Wildlife Service, P.O. Box 1967, Hurstville, NSW, Australia 2220) 1991. The effect of 200 years of European settlement on the vegetation and flora of New South Wales.* Cunninghamia *2(3): 343-370.* The vegetation of New South Wales is dominated by *Eucalyptus* (and other Myrtaceous genera) and *Acacia* and reflects adaptations to climatic change during the late Tertiary and Quaternary and to 38–45,000 years or more of Aboriginal burning. Of the ca. 6000 vascular plants in NSW, 1198 are alien and naturalised originating from Europe, Asia, the Americas, South Africa and the Mediterranean. At least 532 native species are rare or threatened. The native flora has been previously tentatively classified into 432 associations in 18 major community groups. Grazing and cropping have been the major causes of decline in the distribution and abundance of these associations and of rare or threatened species, but additional factors are urban expansion, forestry and invading weeds. Examples are *Rutidosis leptorhynchoides*, an endangered plant threatened by grazing and urban expansion, the recently cleared *Acacia harpophylla* forests, and coastal vegetation threatened by the invasive weed *Chrysanthemoides monilifera*.

Of the total area of NSW, 4.86% is reserved for conservation as of 1990; an estimated 42 per cent of plant associations and 49 per cent of rare or threatened species are adequately conserved as of 1990. Further survey and reservation is needed, particularly in tall open forests, wetlands, semi-arid and agricultural lands. Further research is required into endangered species, their habitats and the processes causing decline in populations.

Introduction

While Dutch and English sailors landed on the western and northern shores of Australia in the 17th century, it was Captain James Cook's voyage in 1770 that led to the first European settlement of Australia in 1788 on the east coast, where the city of Sydney now stands.

In the ensuing 200 years of European settlement of Australia, much of the vegetation has been greatly altered in abundance and distribution. Species have become extinct due to the activities of man, alien plants have been introduced, many becoming weeds in competition with native species, and some ecosystems are under severe threat because of over-exploitation. Adamson and Fox (1982) go so far as to suggest that no other continent has experienced such a rapid change.

Wells et al. (1984) estimate that forests, woodlands and tall shrubs covered 77-88% of New South Wales in 1788. Over half of this vegetation has been cleared, primarily for agriculture (Department of Arts, Heritage and Environment 1986, Reed 1990); During the first 130 years of European settlement 35.3 million hectares (44% of New South Wales) were ring-barked or partially cleared (Reed 1990). Furthermore, during a five year period in the 1980s, at least 2.2 million hectares were cleared. This represents a rate of 1183 hectares/day (Reed 1990). Land-clearing continues today in most parts of the State with indifference to contemporary views about the causes of land degradation, for example, the views expressed in the Murray-Darling Basin Natural Resources Management Strategy (Murray-Darling Basin Ministerial Council 1989).

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Pre-European history of the vegetation of south-east Australia

The history of Australia's vegetation is well documented by Beadle (1981), Barlow (1981), Groves (1981), Smith (1982) and White (1986). It is briefly discussed here to establish the environmental factors and previous human impact that have affected the vegetation.

After long periods of relative stability of climate and vegetation formations over most of the Tertiary, climate became more unstable in the Pliocene-Pleistocene epochs (Singh 1982). Rainforests covered much of Australia in the mid-Tertiary but retracted with the onset of cooler and drier climatic trends. Pollen diagrams from Lake George in south-east New South Wales (Singh, Kershaw & Clark 1981), and Lynch's Crater in north-east Queensland (Kershaw 1978) detail changes in vegetation during the latter parts of the Pleistocene. These changes principally comprise oscillations between rainforest plants and dry sclerophyll plants.

A tentative reconstruction, based on somewhat limited data, is given by Ross (1984) who describes the major environmental changes in south-east Australia over the late Quaternary. By about 32,000 years ago south-east Australia experienced interstadial conditions that were cooler and wetter than today. Rainforests had retreated to refugia and grasslands dominated high country and semi-arid regions of the continent. During the last ice age between about 25,000 and 12,000 years ago the vegetation adapted to dry, cool conditions. Grasslands were common and forests became more sparse in their structure. When the ice age ended the treeline rose and forests once again expanded, with *Casuarina* invading many areas. Rainforest also expanded from its refugia (Webb & Tracey 1982). This corresponded with a relatively wet period up to 5000 years ago. During a slightly drier period between 3000 and 1000 years ago some areas reverted to more grass-dominated vegetation (Ross 1984). The present-day slightly less xeric vegetation types were established during the last 1000–1500 years (Ross 1984).

The impacts of Aborigines on Australian vegetation

It is difficult to specify the effect of 45,000 (Nanson, Young & Stockton 1987) to 60,000 (Wright 1986) years of Aboriginal practices on Australia's vegetation because they occupied the continent simultaneously with great changes in climate.

The most significant way in which Aborigines may have altered their environment would have been through the use of fire. The reasons attributed to Aborigines using fire include: flushing game (Barrallier 1802, Hunter 1793); to stimulate seed production of edible plants, for example cycads (Beaton 1982); to stimulate the growth of young shoots, thereby increasing the amount of food for game in an area (Lewis 1982); easing travel through the countryside; signalling; and frightening enemies.

Over the last few decades there has been a good deal of debate over the extent of change to the Australian vegetation caused by Aboriginal burning. Tindale (1959) followed by Jones (1969) suggests that Aborigines had radically altered the environment through their use of fire. Alternatively, Horton (1982) postulates that Aborigines were conservative when using fire and merely maintained natural fire patterns in vegetation.

Bowman and Brown (1986) reject Horton's model of fire-vegetation relations by citing data that support the view that frequent burning favours plants adapted to fire and increases the probability of fire. They maintain that Aborigines were capable of burning mature forests in regions of low fire frequency thus causing changes to the vegetation e.g. from *Nothofagus* forests to sedgelands. However, the survival of the fire-sensitive pencil pine *Arthrotaxis cupressoides* during Aboriginal occupation in the Alpine zone of Tasmania, and its subsequent decline due to European firing, indicates that Aborigines used fire differently from Europeans or did not occupy and burn all regions (Bowman & Brown 1986).

Although evidence is lacking, it is likely that some plant species are now threatened because they were favoured by Aboriginal burning regimes which are now absent. Examples include species of *Swainsona* (Fabaceae) (Parsons & Browne 1983). Conversely, some species may have become rare primarily due to Aboriginal burning.

A general agreement beginning to emerge about the level of Aboriginal impact on Australian vegetation through their use of fire (Clark 1983, Bowman & Brown 1986), lies somewhere between the views of Horton (1982) and Jones (1969). Clark (1983) concludes that 'it is likely that Aborigines played a maintenance role to the major determinant of vegetation, climate'. There are certainly numerous records in the journals of early European explorers such as Mitchell in New South Wales (1848) and Robinson in Tasmania (1829–1834) describing the common Aboriginal practice of firing the vegetation but it is difficult to weigh the relative importance of Aboriginal use of fire against climatic change. Also, we do not have enough knowledge of the differences in Aboriginal use of fire between different groups and in different parts of Australia. Whatever the causes, the vegetation that was present in most regions when Europeans arrived was well adapted to fire (Gill 1975).

The present vegetation of New South Wales

New South Wales contains a range of plant associations as a consequence of steep north-south and east-west environmental gradients. This diversity in associations is reflected in the richness of plant species (Table 1).

Table 1. Number of vascular plant species in New South Wales (from Jacobs & Pickard 1981)

Plant group	No. native species	No. naturalised species (%)	Total
Pteridophyta	199	5 (3)	204
Gymnosperms	25	3 (11)	28
Angiosperms (monocots)	1171	314 (21)	1485
Angiosperms (dicots)	3569	876 (20)	4445
Total	**4964**	**1198 (19)**	**6162**

The majority of the plant associations present today are dominated by *Eucalyptus* or other trees and shrubs in the Myrtaceae, or *Acacia* in the Fabaceae. Exceptions are alpine and rainforest plant associations and chenopod shrublands of the interior. With the exception of rainforest flora, most of the flora in New South Wales displays xeromorphic characteristics. Xeromorphism has evolved as an adaptation to infertile soils and/or lack of water (Beadle 1981). Many xeromorphic genera and species have evolved from rainforest species (Andrews 1916, cited in Beadle 1981; Webb & Tracey 1982). Proteaceae has rainforest genera such as *Stenocarpus*, *Orites*, and *Macadamia* but also xeromorphic genera such as *Hakea*, *Grevillea* and *Banksia*.

The distribution of plant species in New South Wales is skewed towards the eastern, moister and more complex (in terms of substrates and topography) botanical divisions of the State. The drier western plains that cover more than half of the state contain far fewer plant species than do the eastern ranges and coast. Cunningham et al. (1981) list approximately 2000 taxa of plants occurring in western New South Wales, yet a comparable number of plant taxa are present within the Sydney region on the east coast (Beadle, Evans & Carolin 1982).

Localised endemism is also more common in the eastern parts of New South Wales where varied geologies, greater variation in local climate and isolated tablelands or mountains have favoured the evolution of distinctive floras. Such areas include: the alpine zone of Kosciusko National Park on the Southern Tablelands with 21 endemic species of vascular plants (Costin et al. 1979); the southern escarpment overlooking the Jamieson Valley in the Blue Mountains (Keith & Benson 1988); outlying mountains on the South Coast and the Northern Tablelands; and the subtropical rainforest remnants of the 'Big Scrub' area on the far North Coast.

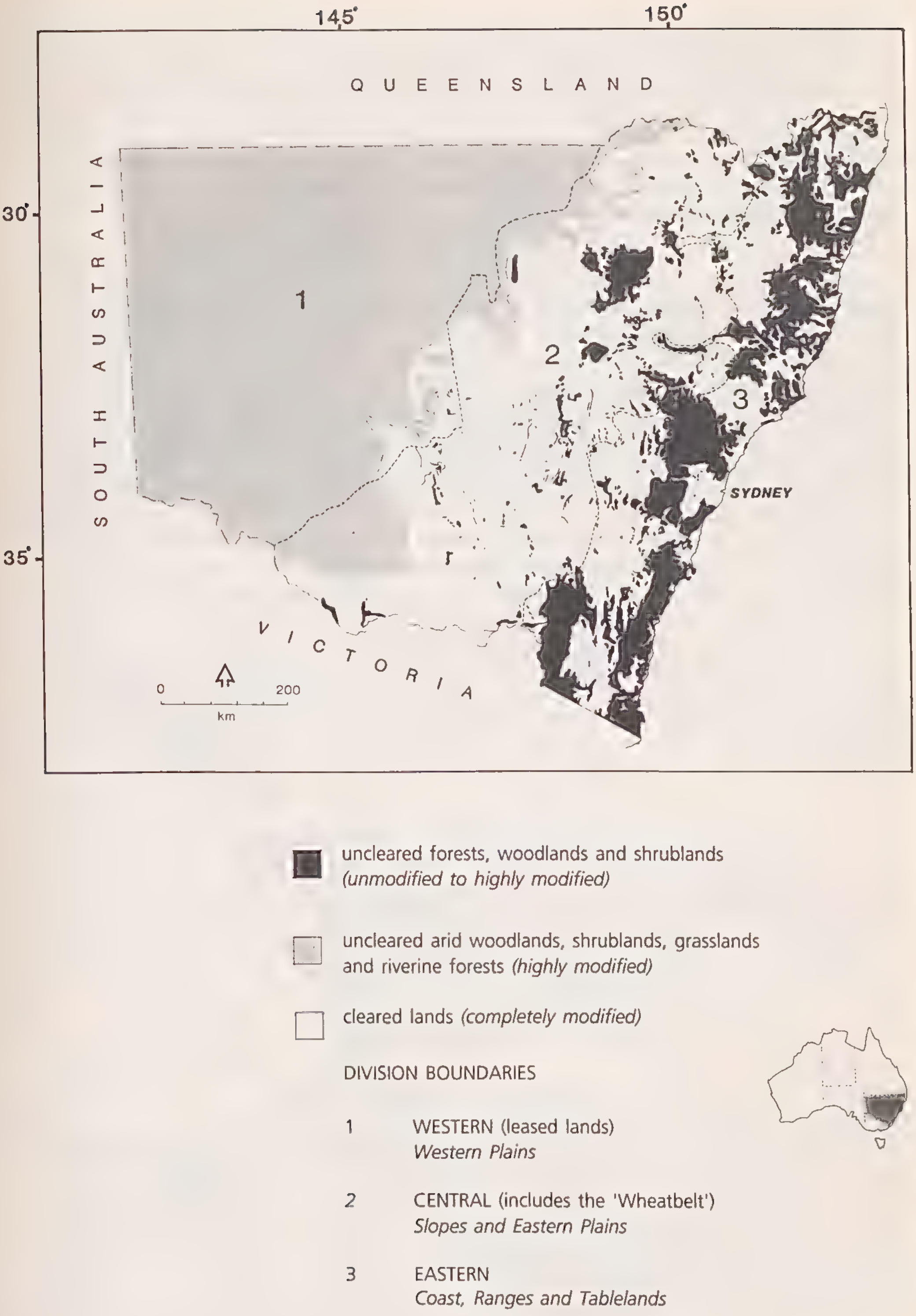
Beadle (1981) erected a floristic classification for Australia's vegetation. This has been refined by Benson (1989) for New South Wales, in which 432 plant associations are listed. These associations are allocated to 18 vegetation groups (based on the Beadle 1981 classification) reflecting the major biogeographic provinces of the State. This classification is currently being revised (Hager & Benson 1990; Robinson & Benson 1990).

Effect of European settlement on the vegetation of New South Wales

Most of New South Wales has either been moderately or highly modified by humans since European settlement 200 years ago (Adamson & Fox (1982), Leigh et al. (1984), (Figure 1). The regions that have been most markedly altered (besides urban centres) are those that contain better soils on flat to undulating topography. They include the coastal alluvial valleys and plains, basalt plateaux, the less steeply sloping tablelands and the Central Division of the State incorporating the Western Slopes and eastern parts of the Western Plains.

At the time of European settlement rainforest covered about 1% of New South Wales, but because it occupied rich soils, some of the largest expanses (for example the Big Scrub and on the Illawarra) were cleared by the mid 19th century (Frith 1977; Strom 1977). Today, only about one quarter of the original rainforest (192,000 hectares) remains structurally intact (Floyd 1990). The largest remaining stands are now protected in reserves and are registered on the World Heritage List.

Very little of the various associations of tall moist forest occurring on higher nutrient soils on the eastern tablelands and coast remain undisturbed. Initially clearing for settlement and agriculture eliminated much of this habitat from the coastal valleys and flatter parts of the tablelands. With the exception of some relatively small stands



■ uncleared forests, woodlands and shrublands *(unmodified to highly modified)*

▨ uncleared arid woodlands, shrublands, grasslands and riverine forests *(highly modified)*

☐ cleared lands *(completely modified)*

DIVISION BOUNDARIES

1	WESTERN (leased lands) *Western Plains*
2	CENTRAL (includes the 'Wheatbelt') *Slopes and Eastern Plains*
3	EASTERN *Coast, Ranges and Tablelands*

Figure 1. Modification of the native vegetation of New South Wales since European settlement in 1778.

in conservation reserves, most of the remaining tall forest has been or is presently being logged and subject to changed fire regimes, including frequent control burning. This has significantly changed the age/size structure of these forests and the composition of the understorey. Regenerating forests on both public and private land are coming under increasing pressure for exploitation as timber resources run low and alternative uses of timber are being proposed for supplying woodchip exports, pulp mills and export firewood (NSW Department of State Development 1989; National Parks and Wildlife Service of NSW 1990).

Even in areas where woodlands or forest were left uncleared, subsequent grazing produced a series of changes in the understorey which are hard to assess today because very few detailed descriptions of the flora were made by early explorers or settlers. The *Eucalyptus albens* and *E. melliodora – E. blakelyi* woodland associations on the Central Western Slopes were drastically affected by early settlement; probably over 90% of these woodlands have been lost. Those areas not cleared have been subject to heavy grazing pressures. Moore (1966) describes some of the changes to understorey plant species over time due to grazing in these woodlands. Beginning with tall warm-season perennial grasses such as *Themeda australis* and *Poa caespitosa,* sheep grazing led to these being replaced by short, cool season perennials (other native species) and herbs. Further grazing led to the influx of cool-season annuals, mainly introduced species with Mediterranean origins. Superphosphate application further favoured annuals over perennial species of plants.

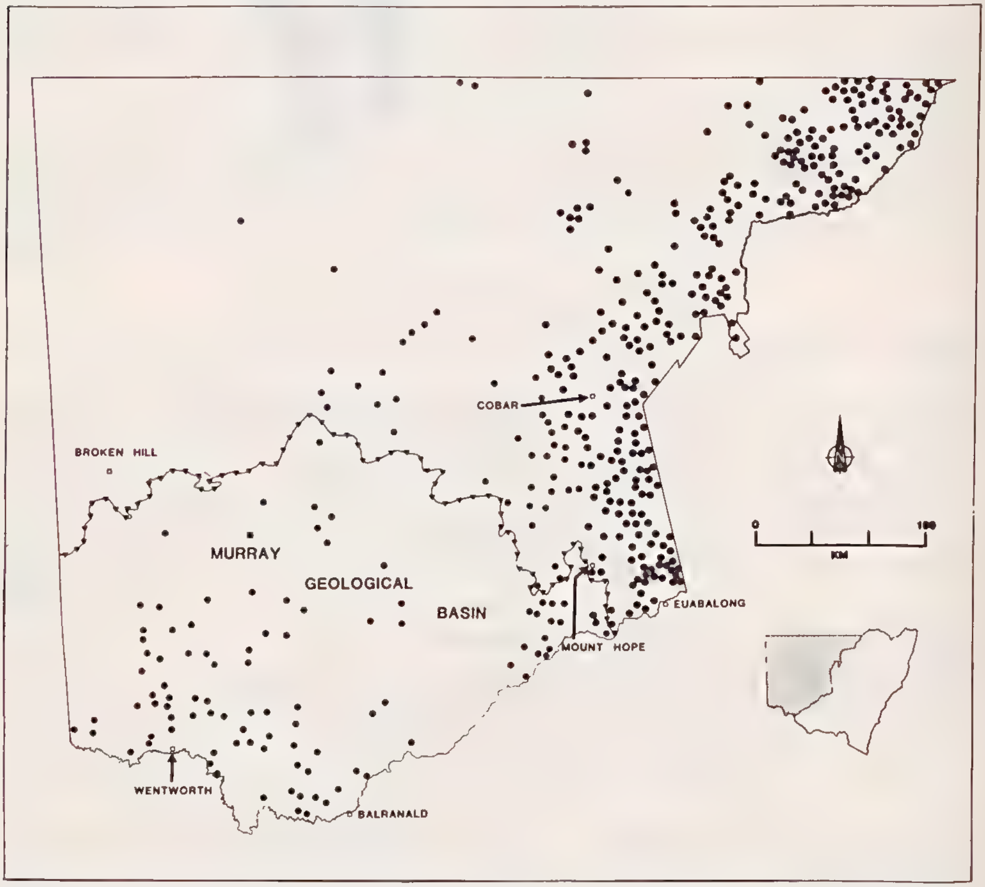


Figure 2. Location of clearing licences granted in the Western division 1984–1989 (from Pressey 1990).

The Central Division (Figure 1) has largely been cleared. This clearing is continuing to encroach into marginal lands to the west (Figure 2). Between February 1984 and November 1989 the Western Lands Commission granted clearing licences for over 560,000 hectares, although this overestimates the amount of land actually cleared (Pressey 1990).

The Western Plains of New South Wales have been grazed extensively since the 1830s, first by cattle then sheep (Heathcote 1965). Denny (1987) compares present-day vegetation with that noted by Sir Thomas Mitchell, Surveyor General of New South Wales, who explored the western river systems in the 1830s. An example is given for a site along the western section of the Murray River:-

Mitchell (1838): '*We crossed grassy plains bounded by sandhills on which grew pines [Callitris], and open forests of goborro (or box tree) prevailed very generally nearer the river...... the remarkable incident of this day's journey, was the discovery of an animal.....*'

The present-day vegetation at this locality has been highly modified. Much of the sand-hill vegetation has been cleared and some of the *Eucalyptus largiflorens* (Box Tree) has been ringbarked (Denny 1987). The animal discovered was the pig-footed Bandicoot (extinct by 1900). Denny records that 80% of the localities checked against Mitchell's notes in this region now have a decreased canopy and middle stratum in their vegetation.

Overgrazing by stock and other introduced animals, particularly the rabbit, combined with severe droughts and a lack of appreciation of the fragility of the environment, particularly the soils, have led to large scale degradation and changes in abundance of native plants and animals. The more palatable plants suffered most. For example, on the Riverina there has been a shift from chenopods to grassland and the reduction of such conspicuous perennials as Old Man Saltbush, *Atriplex nummularia* (Moore 1953). Five of the 11 native species of *Lepidium* (Brassicaceae) and six of the 32 species of *Swainsona* (Fabaceae) (Harden, in press) that have been recorded as occurring in western regions of New South Wales, are now threatened or extinct (Briggs and Leigh 1988).

Since settlement it is estimated that 56% (24 species) of all native mammals that once inhabited these regions are now extinct (National Parks and Wildlife Service 1982). These detrimental impacts on plants and animals in semi-arid regions have come about due to competition with introduced plants and animals, overgrazing and clearing for 'dry-land' cropping in an area with a high frequency of drought. Expanses of scalded country are a conspicuous legacy of past over-exploitation of the outback.

Specific causes of the decline of native vegetation

Grazing

Before European settlement there were no large 'hard-footed' animals or ruminants that could effectively eat dry grass. Domestic and feral animals introduced by European settlers placed increased pressure on native vegetation. Grazing has affected more than 60% of New South Wales and has been the major cause of decline in the vegetation of the State leading to a number of plant extinctions and major reductions in the range and abundance of species and associations (Benson 1989). Clearing has been the cause of decline but other important factors include: alteration of soil structure through compaction and of nutrients through application of fertilizers; erosion, particularly surrounding watering points or on erodible soils or steep slopes; senescence of palatable shrubs and trees with little or no regeneration (Chesterfield & Parsons 1985); changes to fire regimes and introduction of weeds, including the increase of native 'woody weeds' mainly found on the north-western plains. Another indirect effect of grazing is dieback. This refers to the phenomenon of death or decline in health of eucalypt trees in rural areas. In New South Wales it has been most severe on the tablelands and western slopes particularly on the New England Tableland on the Northern Tablelands (Williams & Nadolny 1980). The causes of dieback are currently being researched. Kile (1980) lists defoliation by insects, drought, tree age, soil salinity, mistletoe infestations and root pathogens such as the fungus *Phytophora cinnamomi* as factors associated with rural dieback.

Cropping and irrigation

Covering approximately 20% of New South Wales, cropping is most prevalent in the 'wheatbelt' of the Central Division and on coastal valleys and plains. Irrigation is common to many river systems with drastic effects on water supplies along the inland rivers. Because of the intensive nature of cropping there is usually total destruction of the native vegetation and it is difficult for it to re-establish. Intensive cropping has also led to soil structure decline. The nutrient status in soils is altered by ploughing and the application of fertilizers the latter leading to acidification in many places. Pesticides and herbicides affect non-target species in the surrounding natural biota. Introduced weeds, both terrestrial and aquatic, out-compete native species and reduce their abundance.

Salinity is a major problem in areas subject to cropping and grazing, for example, 920,000 hectares (mainly saline scalds) of the Murray–Darling Basin are affected by salination (Murray–Darling Ministerial Council 1989). Dryland salinity caused through the impact of rising water tables is estimated to be affecting 14–20,000 hectares in New South Wales (Keith Emery, Soil Conservation Service pers. comm.). In 1985, 9000 hectares of the Murray, Murrumbidgee and Wakool irrigation areas were visibly affected by salinity through rising water tables and this is projected to increase many times over the next 50 years (Peter Rooke, Water Resources Commission pers. comm.).

Forestry

As of June 1990 3,663,329 hectares (4.6%) of New South Wales was publicly managed for wood production, mainly on the east coast and tablelands but also the *Callitris* woodlands in the central parts of the State. Private lands are also logged. Logging practices range from selective logging to clearfelling for woodchips or pine plantations. These practices result in reduction in native forest areas, younger age classes, soil erosion (Forestry Commission of NSW 1988), changes in the microclimate affecting understorey species, introductions of weeds and pathogens (Ecos 1978) and changes in fire regimes (Fox 1990; Dickinson & Kirkpatrick 1987). Historically, the passing of the Forestry Act in 1916 played a major role in flora conservation by at least protecting areas from total clearing for agriculture. However, the recent trend towards more intensive forestry (Office of State Development 1989), could limit the conservation options for a number of forest associations and their constituent species on the tablelands, eastern escarpment and coast (National Parks & Wildlife Service 1990). By 2005 large areas of *Pinus radiata* plantations will have matured and increasingly they will replace native eucalypt forest in supplying both sawlogs and woodchips (Cameron & Penna 1988; Clark & Blakers 1989). In the interim, the future of the remaining unprotected, unlogged, aesthetically appealing, tall eucalypt forest growing on high- to medium nutrient soils will probably continue to be a topic of public debate.

Urban and industrial expansion

During the 1970s 60,000 hectares of land in New South Wales was developed for housing, industry or roads (Department of Arts, Heritage & the Environment 1986).

The figures for the 1980s are probably higher. Urban expansion is mainly affecting the coast. For example, in Sydney it is endangering a number of plant species, e.g. *Pimelea spicata, Grevillea caleyi, Eucalyptus camfieldii* and *Acacia pubescens,* and distinctive plant associations such as the Cumberland Plain woodland dominated by *Eucalyptus moluccana* and *E. tereticornis.* Besides direct destruction of the vegetation, weeds and pollution are major consequences of urbanisation. At Wentworth Falls in the Blue Mountains, the largest population of the endemic podocarp *Microstrobos fitzgeraldii* is threatened by excessive algal growth resulting from pollution in the catchment (Smith 1981; Brown 1990).

Mining and quarrying

The effects of extraction industries tend to be localised, but involve total loss of the vegetation. Revegetation depends on the nature of the mining and post-operative rehabilitation works. On the North Coast, beach sand-mining has eliminated some of the largest stands of littoral rainforest e.g. between Harrington and Crowdy Head (Floyd 1979). Underground mining for coal in the Sydney Basin can have detrimental impacts on swamps if hydrology changes as a result of land slumping (Young 1982; Nanson & Young 1983). Pollution and sedimentation downstream from mine sites can severely impede the health of aquatic and riverine vegetation.

Introduced plants

Approximately 20% of vascular plant species in New South Wales are naturalised exotics. Some of these have become major weeds to agricultural and natural environments. Characteristics of weeds include high colonising capacity, efficient dispersal and ability to reproduce rapidly (often asexually) (Groves 1986). Some of the major weed species in New South Wales affecting natural areas are: Lantana (*Lantana camara*), Boneseed and Bitou Bush (*Chrysanthemoides monilifera*), Privet (*Ligustrum* spp.), Camphor Laurel (*Cinnamomum camphora*), Crofton Weed (*Ageratina* spp.), Blackberry (*Rubus* spp.), English Broom (*Cytisus scoparius*) and Groundsel Bush (*Baccharis halimifolia*). Introduced members of the Asteraceae, Brassicaceae and Amaranthaceae are commonly invasive plants. *Salvinia molesta* and *Eichhornia crassipes* are major aquatic weeds. Eradication or control of weeds is expensive. Biological control provides the best option for controlling some weeds and investigations for some species are being carried out. The *Cactoblastis* moth – *Opuntia stricta* (Prickly Pear) case (Dodd 1959), remains the most successful example of biological control to date. Currently there are biological control studies underway for Bitou Bush *Chrysanthemoides monilifera* (John Scott pers. comm.), English Broom *Cytisus scoparius* (Hosking 1990) and *Lantana camara.*

Table 2 outlines the relative importance of various causes on the decline of natural plant associations in New South Wales. Evidence for decline or change in vegetation is outlined in Table 3. Reductions in abundance and distributions of plant associations are the most important aspects of the impact of European settlement.

Threats to plant species

In New South Wales, 14 plant species are reported as extinct; a further 12 plant species are no longer found in the State but exist in other parts of Australia; 213 plant species are threatened, of these 56 are endangered and 157 are vulnerable; 279 are rare and 26 plant species are presumed to be rare though their exact status is unknown (Briggs & Leigh 1988).

Table 2. Causes of decline or change to plant associations in New South Wales. Figures are derived from assessments made in Benson (1989).

Cause	**Percentage of plant associations affected**
Grazing/clearing	45
Cropping/clearing	18
Forestry	13
Changes in fire regime	6.5
Urban and industrial expansion	6
Drainage and irrigation	5.5
Mining and quarrying	3.5
*Competition with weeds	<2
*Recreational pressures	<2
*Herbicides and pollution	<2

Notes: * These causes of decline are likely to increase in the future.

Table 3. The proportion of plant associations subjected to various changes since European settlement. Figures are derived from assessments made in Benson (1989).

Nature of change	**Percentage of plant associations affected**
Reductions in range	
Minor reductions in range and/or abundance	36
Major reductions in range and/or abundance	29
Changes in age classes	
Younger age classes over much of an association's distribution (mainly due to forestry practices)	16
Older age classes over much of an association's distribution (mainly due to lack of regeneration due to grazing in pastoral areas. Also including delayed response including 'dieback'.)	10
Major alteration to the understorey	9 *
Increased abundance	1

Notes: *This is a conservative estimate because the understoreys of most plant associations have been altered to some degree. The term 'major' here implies loss of the majority of under storey plant species. Examples would be the box woodland associations on the western slopes.

Table 4. Causes for the extinction and threatened status of species of vascular plants in New South Wales derived by the author based on Leigh, Boden & Briggs (1984), unpublished works, and personal observation.

Cause	X	E	V	Total	%
Agriculture (grazing/cropping)	16	29	67	112	41
Forestry activities	-	2	10	12	4
Urban and industrial	1	5	14	20	7
Mining and quarrying	-	2	10	12	4
Change in fire regime/disturbance	1	5	23	29	11
Competition with introduced plants	-	1	4	5	2
Herbicides/pollution	-	2	1	3	1
*Collection pressures	-	3	6	9	3
**Low numbers	-	18	49	67	24
Recreation, e.g. trampling	-	-	2	2	1
Hydrological changes	-	4	-	4	2
Total	**18**	**71**	**186**	**275**	

Notes: Risk codes: X = extinct; E = endangered; V = vulnerable as defined by Briggs & Leigh (1988).
'Rare' species are excluded as they are not considered to be threatened.
Many species are affected by more than one cause.
* species threatened by uncontrolled collecting of whole plants or part thereof.
** species threatened because their population(s) are very small (usually less than 300). This may be natural or caused directly or indirectly by other factors.

The main causes for the extinction of or threats to plants in New South Wales (Table 4) are similar to those threatening plant associations — grazing and clearing. *Acacia carnei* is one of the many rare plants suffering from overgrazing. Research into its population dynamics in populations within Kinchega National Park reveal that there is little or no regeneration occurring from rootstock or seedling and there is advanced senescence of mature plants (Auld 1990). The main cause in its decline is rabbits. Where rabbits are less abundant, mature plants are far healthier and there is some recruitment from root-suckers (Auld 1990).

The 'low numbers' category includes species that had 'naturally' small populations (in the order of hundreds of individuals or less) at the time of European settlement and species that may have attained such small populations as a consequent of other causes. When they exist in small populations the long term viability of species is threatened due to genetic drift and consequent loss of fitness to adapt to change (Jarvinen 1982; Brown 1983). This could include possible rapid change in climate due to the Greenhouse Effect.

Some plant species may be endangered because they require particular environmental conditions such as disturbance to complete their life cycle, but now fail to get it due to human interference. Disturbance may take the form of fire, flooding, natural erosion and soil disturbance caused by burrowing animals. Both *Rutidosis heterogama* and *Olearia flocktoniae*, (Asteraceae) (presumed extinct until they were recently rediscovered on the North Coast) were located in disturbed sites; *R. heterogama* along a recently burnt fire trail in Bundjalung National Park, and *O. flocktoniae* on a recently graded roadside batter in a State Forest near Coffs Harbour.

Eriocaulon carsonii (Eriocaulaceae) illustrates a more indirect effect of European settlement. It only grows on a few mound springs in South Australia and one in the far north-western part of New South Wales. Many natural mound springs have been exploited for artesian water for stock and outback settlements, reducing the supply of water and hydrostatic pressures in the artesian basins. This has lead to a decline in the mound springs and the habitat of *E. carsonii* (T. Fatchen pers. comm.). The mound springs have also been physically damaged by the effect of stock trampling.

Uncontrolled collecting of some species is causing their decline. In New South Wales this is particularly so with orchids — *Sarcochilus fitzgeraldii* and *Phaius tancarvilliae* to name two. Australia's rarest eucalypt, *Eucalyptus recurva* (Crisp 1988), which has a population of six growing in two stands near Mongarlowe on the Southern Tablelands (R. Lembit pers. comm.), is threatened by collectors of seed and specimens. Collection pressure is a far greater threat to plant species in Western Australia where there is a substantial export cut flower trade, although this trade is closely monitored by the Western Australian Government.

Introduced naturalised flora

The large-scale invasion of alien plants began with European settlement in 1788. By 1804 the botanist, Robert Brown, had noted 29 introduced plants in Sydney (Groves 1986).

It is not surprising that Europe, Africa and Asia are major sources of alien plants considering the origin of the early settlers and their routes of immigration to Australia. Most of the settlers came from Britian, Ireland or Europe and they would have imported plants either intentionally or accidentally from their homelands. One example is *Lantana camara* (Verbenaceae) which as early as 1846 was present as an ornamental in the garden of Lady Innes at Port Macquarie on the north coast of New South Wales (Boswell 1981). It is now one of the most abundant weeds in coastal parts of the State and in south-east Queensland.

Kloot (1987b) suggests that, over time, plants from climatic regions more comparable with Australia have invaded. This explains the high numbers of naturalised, alien plants from the Mediterranean Region, the Americas and Africa.

Michael (1981) suggests that approximately 10 per cent of Australia's vascular flora are introduced (alien). Of the vascular flora of New South Wales 20 per cent are introduced and naturalised, (Table 1) (the term 'naturalised' is based on the definition of Thellung 1912 cited in Michael 1981). While only about five per cent of introduced plants have become naturalised in Australia and only approximately one per cent have become weeds (Michael 1981), alien plants have continued to have a significant impact on native flora. Asteraceae, Brassicaceae, Poaceae, Boraginaceae and Amaranthaceae are conspicuous in containing large numbers of alien, naturalised plants (Table 5). In western New South Wales approximately one third of all grasses are naturalised aliens (Cunningham et al. 1981).

Indigenous species also have invaded other parts of the continent: *Pittosporum undulatum* (Pittosporaceae), a native of coastal south-eastern Australia, is expanding its range and abundance in southern Victoria and in South Australia (Gleadow & Ashton 1981); *Acacia dealbata* (a native of eastern New South Wales) is spreading rapidly in Western Australia (Groves 1986) and *Acacia saligna* (a native of Western Australia) is expanding in some coastal regions of New South Wales.

Some of the invaders pose major threats to native vegetation. For many weeds, biological control is the only feasible solution but, as Groves (1986) points out, there is a need for more study into the genetics in weed populations to improve the theoretical base for biological control programs.

Fox & Fox (1986) consider that there is no invasion of natural communities unless there has been previous disturbance. One of the weeds threatening native vegetation

Table 5. Plant families with large numbers of alien naturalized species (from Kloot (1987b).

Dicotyledonous families	No of species
Asteraceae	153
Fabaceae (inc. Faboideae, Mimosoideae and Caesalpinioideae)	110
Brassicaceae	49
Caryophyllaceae	34
Solanaceae	38
Rosaceae	45
Lamiaceae	24
Scrophulariaceae	33
Monocotyledonous families	
Poaceae	208
Iridaceae	26
Cyperaceae	21

which comes closest to contradicting this view is *Chrysanthemoides monilifera*, the major weed along beaches in eastern and southern Australia. While this South African colonising species gained a strong foothold in Australia largely on disturbed sites, particularly coastal sand dunes, it is now displacing native species (Weiss 1983, Weiss & Noble 1984). It is detailed in a case study below.

Case studies

The following three case studies illustrate some influences of European settlement on plant communities and plant species, either directly through clearing or modification of the landscape, or indirectly through the introduction of alien plants that have become weeds and out competed native flora.

A threatened plant community: Brigalow

Acacia harpophylla F. Muell. ex. Benth. (Fabaceae) known as Brigalow spans from central northern Queensland to the North-Western Plains of New South Wales (Figure 3) (Sattler & Webster 1984). There are some isolated records further south in central NSW.

In Queensland it once covered about 4.7 million hectares, in New South Wales about 250,000 hectares (Pulsford 1984). In some Brigalow communities it is the only species in the upper stratum, and the understorey features few other plants. In others it is found with other *Acacia* species, *Eucalyptus*, or associated with semi-evergreen vine thickets (Johnson 1964, 1984). In moister regions and on better soils, Brigalow grows up to 20 m high. It mainly occurs on clay soils and in New South Wales these have developed from Quaternary alluvium over sedimentary strata (Isbell 1962, Pulsford 1984).

Unlike many of the other inland plant communities the bulk of the Brigalow country was left uncleared until after World War II. This was partly due to the difficulty of clearing Brigalow as it resprouts readily from rootstock and partly because of the major infestations of a pest, Prickly Pear (*Opuntia stricta*), over much of its range until controlled by the Cactoblastis moth. Favourable assessments of the soil under Brigalow for growing crops led to massive clearing operations in the 1950s and 1960s.

Brigalow is now one of the rarest plant communities in New South Wales. In Queensland only 0.5% of the estimated pre-settlement area of Brigalow is reserved and less than 1% in New South Wales (Sattler & Webster 1984, Pulsford 1984). Clearing still goes on, particularly in the northern parts of its range in Queensland that Lloyd (1984) views as Australia's last agricultural 'frontier'.

In the Narrabri–Bogabilla region of New South Wales only small amounts of Brigalow remain, usually in stands of less than 400 hectares (Pulsford 1984). A large stand of Brigalow survives 100 km north-east of Bourke, west of the Culgoa River. This population is several hundred kilometres west of the main band of Brigalow (Figure 3). Part of this population is under threat from clearing by lessees.

Improving the conservation status of Brigalow is now a priority of both the Queensland and New South Wales National Parks and Wildlife Services. Two small reserves have been established near the town of Narrabri in New South Wales and a number of others are being investigated. Protecting and reserving viable stands of Brigalow north-east of Bourke should be a priority.

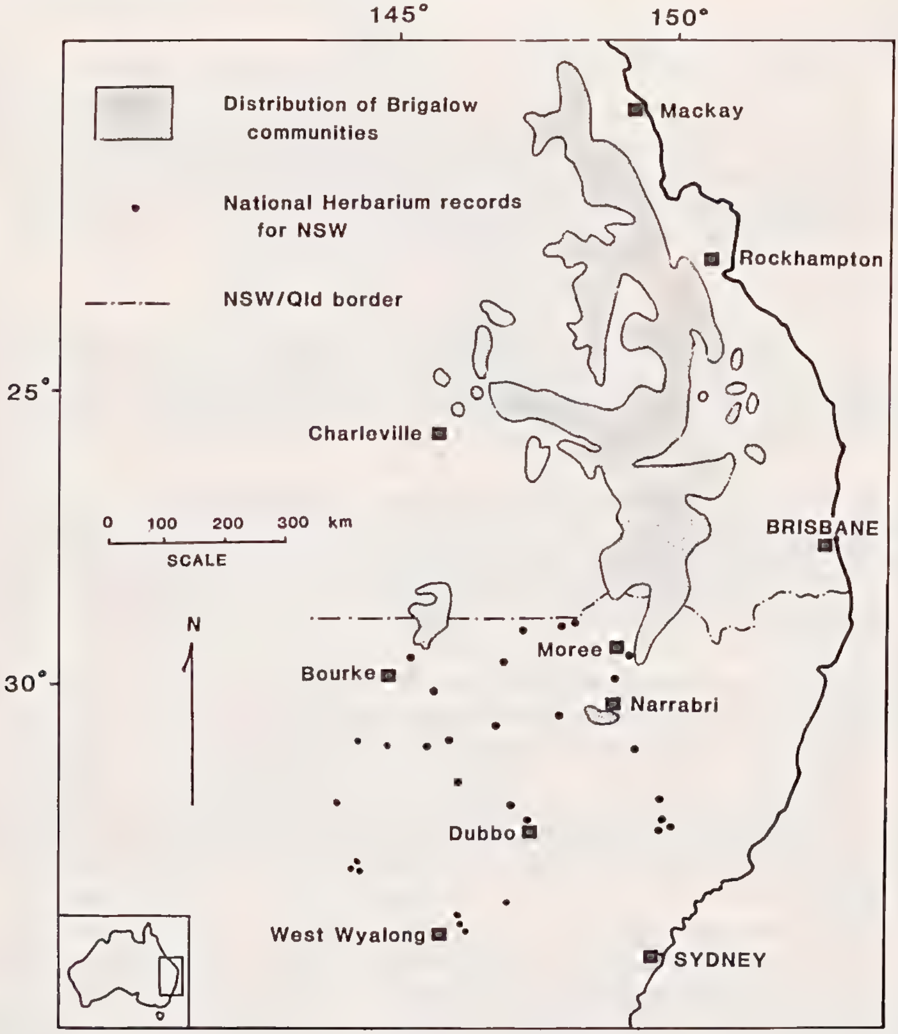


Figure 3. Distribution of Brigalow (*Acacia harpophylla*) in Queensland and New South Wales. Most of the larger stands near Narrabri and Moree in NSW have been cleared: only a few thousand hectares remain in scattered remnants. (Derived from Adamson & Fox 1981 and Pulsford 1984).

An endangered plant: Rutidosis leptorhynchoides

There are about 10 species of *Rutidosis* in Australia and four of these are listed as threatened (Briggs & Leigh 1988). *R. leptorhynchoides* F. Muell. (Asteraceae) is a bushy, perennial herb up to 30 cm high, flowering in the warmer months, particularly November and December. It was once more widely distributed in grasslands and woodlands in southern Victoria, centred on the basaltic Keilor Plain north west of Melbourne and in the Canberra–Queanbeyan districts on the Southern Tablelands of New South Wales.

The Victorian populations occur in communities dominated by Kangaroo Grass, *Themeda australis*. Most of the remaining sites near Melbourne are within railway reserves. One population has been observed to decrease from 100 plants to 11 plants over the last 10 years due to unsubstantiated causes (Leigh et al. 1984). In other recorded localities the species has become extinct.

In the Canberra–Queanbeyan area several populations of *R. leptorhynchoides* still occur, although it has suffered a substantial decline in its abundance due to urban expansion. One population on the outskirts of Queanbeyan has been protected in a small 2.2 hectare nature reserve. A few small populations in the Australian Capital Territory are threatened by urban development.

In Victoria, *R. leptorhynchoides* has mainly come under threat from grazing (Scarlett 1979). Fire could also be an important factor in its decline and Scarlett has suggested that summer burning regimes should be maintained or implemented. Further populations need to be protected in reserves and fenced off from grazing animals. Research into its response to grazing and fire is required.

An alien weed: Chrysanthemoides monilifera

Chrysanthemoides monilifera Norlindh (Asteraceae) is a 'pioneering' shrub that originates from South Africa where its six subspecies occur in a variety of habitats but commonly along the southern coastal areas of that country (Neser & Morris 1985). Two subspecies are present in Australia: *C. monilifera* subsp. *rotunda*, known as Bitou Bush, is established along the Central and North Coasts of New South Wales and the southern Queensland coast in regions of summer rainfall. *C. monilifera* subsp. *monilifera*, known as Boneseed, is found along the South Coast of New South Wales, in Victoria and in South Australia which receive higher winter rainfall.

Chrysanthemoides was first recorded in Sydney and Melbourne in the 1850s as a garden shrub (Gray 1976, Nicholls 1985). The main impetus for its spread was its use as a sand stabilizer on disturbed coastal sand dunes. This use continued even after it was listed as a noxious weed in other States, but ceased when its invasive properties were publicised and better appreciated. *Chrysanthemoides* now occupies 660 km or 60% of the New South Wales coastline, being dominant along about a third (Love 1985). Although approximately 35% of the coast is protected in conservation reserves, over 50% of the coastline in those reserves is affected by Bitou Bush or Boneseed (Love 1985).

The main native plant communities affected are foredune grasslands, dune scrub, dune forest, headland grassy heath and in particular small patches of littoral rainforest. Some rare plants such as *Cryptocarya foetida* (Lauraceae) are highly susceptible to competition with Bitou Bush (Dodkin & Gilmore 1985). Bitou Bush displaces the native shrub *Acacia longifolia* on coastal dunes on the South Coast of New South Wales because of its competitive advantage in the areas of seed production, rate of juvenile root and vegetative growth and an ability to expand vegetatively (Weiss 1983; Weiss & Noble 1984).

Groves (1985) highlights the need for integrated controls for Bitou Bush and Boneseed which would include biological control of seed production and growth vigor, selective use of herbicides, use of fire, and the promotion of indigenous plants to replace *Chrysanthemoides* as it is eliminated. A co-operative Commonwealth and States funded project into a biological control program for *Chrysanthemoides* has been underway for several years and several insect predators have been selected for further assessment and trialing (John Scott pers. comm.).

Conservation of the flora of New South Wales

The first legislation that afforded protection to plants in New South Wales was the *Wild Flowers and Native Plants Act* (1927). This only outlawed the picking of 'protected wildflowers' from Crown land or State Forest. It was replaced by the *National Parks and Wildlife Act* (1974) which, as far as the protection of plant species and their habitats is concerned, is not much better than previous laws (Prineas 1987). New South Wales lacks effective legislation that serves to protect threatened species of plants on all land tenures or recognises the importance of habitat conservation (although draft legislation has been prepared). In contrast, Victoria and Western Australia have strong legislation protecting scheduled plant species (Benson 1990).

Given the lack of effective laws directed specifically at protecting plants, the conservation of flora has mainly been achieved as a consequence of the establishment of reserves to protect scenic or recreational features. However, over recent years there has been more emphasis on reserving or managing lands for the plant communities and species that are poorly conserved or under threat.

In August 1990 the National Parks and Wildlife Service managed 3,854,807 hectares or 4.8% of the State for conservation in 308 conservation reserves (broadly shown on Figure 4). The Forestry Commission manages 137 Flora Reserves (located in State Forests across the State) covering 35,000 hectares (Forestry Commission of NSW 1989). Therefore as of August 1990 a total of 4.86% of New South Wales was specifically dedicated to the conservation of the natural environment.

Large tracts of indigenous vegetation remain outside conservation reserves on public lands and private lands. The public lands include State Forests, unalienated Crown land, travelling stock routes, Crown land reserves and some leasehold lands. Unfortunately, from the conservation perspective, there is now much greater competition for the use of these remaining public lands, whether it be using coastal Crown land for tourist or housing developments or harvesting timber from State Forests in a more intensive way than that practised in the past. Most of the Western Division, representing 40% of the State and incorporating half of the Western Plains and all the Far Western Plains botanical divisions, is leasehold land. Theoretically, there is some government control over land-use in the Western Division but as can be gleaned from Figure 2, clearing is still continuing.

Freehold lands, while in the main highly modified, also contain important vegetation. Some of this is poorly represented on public lands, for example coastal freshwater wetlands and some of the White Box (*Eucalyptus albens)* associations on the Western Slopes. There are presently two key State Environmental Planning Policies affording substantial protection to vegetation types. SEPP 14 covers coastal wetlands and SEPP 26 covers littoral rainforest. Additionally, SEPP 19 protects some of the urban bushland remnants of Sydney.

Of the 432 plant associations listed by Benson (1989) as occurring in New South Wales, 179 (42%) are well represented in reserves, 111 (25%) are either vulnerable or endangered and another 39 (9%) are not at all sampled in the reserve system. Table 6 assesses the conservation and threat status of the 18 major groups of plant associations. Generally, the groups that occur in the Central and Western Divisions are the least well conserved, only approximately 3% of land in these Divisions is protected in conservation reserves (compare Figures 1 and 4). Although there is a far greater proportion of land reserved on the coast and tablelands, i.e. the Eastern Division, it should be emphasised that this Division contains the most diverse, least disturbed and largest natural areas remaining in New South Wales. It is by no means adequately sampled, as those plant associations occurring on richer soils are scarcely represented in reserves, for example the tall eucalypt forests growing on basalt on the Northern Tablelands (Benson & Andrew 1990).

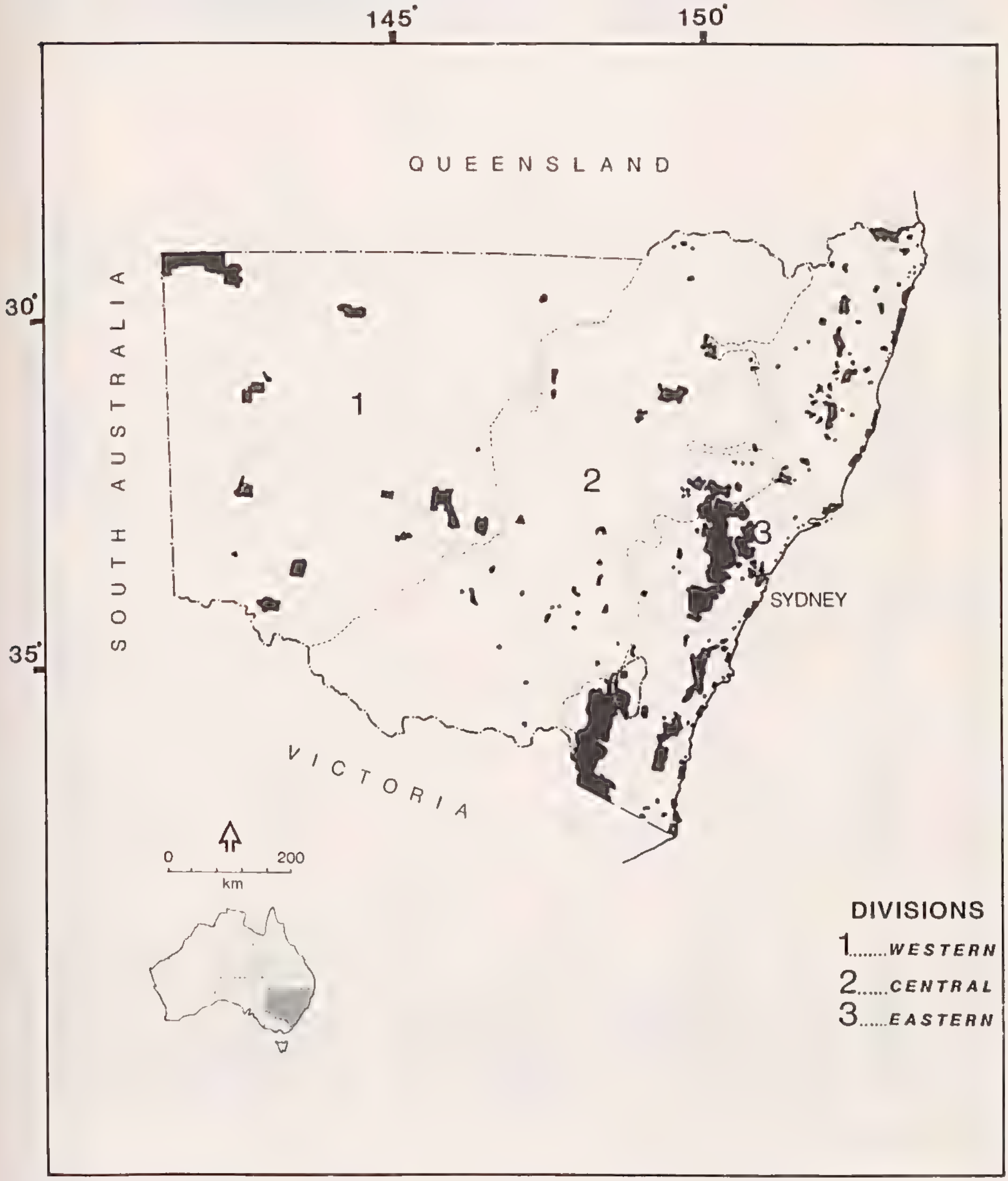


Figure 4. Conservation reserves held by the New South Wales National Parks & Wildlife Service as of 1990.

Table 6. Conservation status of major vegetation groups in New South Wales (from Benson 1989). The figures recorded in the columns refer to the number of plant associations within a vegetation group that are considered to be in a specific risk - conservation code.

No.	**Vegetation group**	**No. of plant associations**	**Risk - conservation code**									**General conservation status**
			E1	**E2**	**E3**	**V1**	**V2**	**V3**	**N1**	**N2**	**N3**	
1	Rainforest											
1(i)	Subtropical rainforest (incl. littoral)	20	1			3	1		6	9		Good: lowland remnants require special protection and management
1(ii)	Dry rainforest	12	3			1	1			4	3	Fair–good: western slopes associations not conserved
1(iii)	Warm temperate rainforest	14								4	10	Excellent
1(iv)	Cool temperate rainforest	11								2	9	Excellent
	Summary - rainforest	57	3	1		1	4	1		16	31	*Good: except for some lowland subtropical, littoral and western dry rainforest
2	Eucalyptus forests mainly on coastal lowlands, medium to high nutrient soils	38					4		5	14	15	Good–fair: some tall forest associations poorly conserved or vulnerable, particularly in forestry or agricultural regions
3	Eucalyptus forests mainly of the coastal lowlands and central tablelands on low nutrient soils	47				3	1	1	3	7	32	Excellent: except for some associations on aeolian sands

No.	Vegetation group	No. of plant associations	Risk - conservation code									General conservation status
			E1	E2	E3	V1	V2	V3	N1	N2	N3	
4	Eucalyptus forests of cooler highland climates (various soil types)	72	3			5	18		1	21	24	Fair: vulnerable associations occur in agricultural zones, particularly New England, Monaro
5	Ironbark forests and woodlands	16	2			2	3		1	6	2	Poor: mostly cleared for agriculture or logged
6	Box woodlands	25	8			6	5		6			Very poor: most vulnerable or endangered in agricultural lands
7	Inland mallee	10		1			3		2	3	1	Fair: some associations vulnerable to clearing for agriculture
8	Banksia and myrtaceous shrublands coastal lowlands - sands and clays	38					1			5	32	Excellent
9	Acacia and myrtaceous shrublands and related highland communities	22				2	1	1		5	13	Very good: except for some northern tableland associations
10	Alpine shrublands, sedgelands and herbfields (Kosciusko NP)	12					2				10	Excellent: but changing land use could threaten some associations
11	*Casuarina cunninghamia* forests	3					1			2		Fair: better conserved in east than in west
12	Inland acacia and casuarina shrubland/ woodlands	13	2	2			3		5	1		Poor: considering distribution; some associations endangered on north-west plains

No.	Vegetation group	No. of plant associations	Risk - conservation code									General conservation status
			E1	**E2**	**E3**	**V1**	**V2**	**V3**	**N1**	**N2**	**N3**	
13	Inland forests and shrublands dominated by 'rainforest' genera	4	1							3		Poor: one endangered, others widely distributed or poorly conserved
14	Halophytic shrubland of the southern plains	9	2			1	2			4		Very poor: little conserved some associations endangered or vulnerable
15	Natural grasslands	26	2				3		3	7	11	Fair: *Astrebla* and *Stipa* poorly conserved
16	Plant associations of the inland water-courses, floodplains and discharge areas	11					2	1	3	5		Very poor
17	Coastal freshwater wetlands and sedgelands	17					7			2	8	Excellent: sedgelands Poor: wetlands
18	Estuarine wetlands	12								6	6	Fair: generally not well conserved below high water mark, particularly sea grasses, and saltmarshes
	Grand total	**432**	**23**	**4**	**0**	**20**	**58**	**6**	**39**	**103**	**179**	

KEY

E = endangered V = vulnerable N = not threatened at this stage
1 = not conserved or, if so, to a very minor degree
2 = inadequately conserved (small areas conserved or geographical range poorly conserved)
3 = adequately conserved (large areas conserved over the major part of its range)

* Statements are made in the context of remaining vegetation. Since two-thirds of subtropical rainforest has been cleared it may never be possible to adequately sample many sites.
See Benson (1989) for the floristic classification of the vegetation of New South Wales.

The most poorly conserved vegetation groups in New South Wales are:

Central and Western Divisions
- box woodlands;
- inland semi-arid 'dry rainforest' remnants;
- halophytic shrublands;
- plant associations along inland watercourses and discharge areas;
- inland *Acacia* and *Casuarina* associations;
- natural grasslands.

Eastern Division
- tall *Eucalyptus* forest associations on higher nutrient soils on the coastal plains and escarpment;
- *Eucalyptus* forest associations of the cooler highland climates, particularly those on richer soils;
- most coastal freshwater wetland types and some estuarine wetland types.

Rare or threatened species

It is estimated that half of the 532 plant species registered as being rare or threatened in New South Wales (Briggs & Leigh 1988) are adequately reserved (Benson 1989), that is with over 1000 individuals being present in reserves. However, this does not necessarily imply these are being managed sympathetically for their long-term conservation.

Although rainforest and alpine plant associations combined cover less than 4% of the State, these contain approximately 20% of the rare or threatened plants (Table 7). These two vegetation groups are relatively well conserved.

While most rare or threatened plant species occur in the Eastern Division of the State, 44% of the vulnerable species are in the poorly reserved and heavily grazed or cropped Central and Western Divisions, thus following the trend identified above for plant associations. Because of the magnitude of the task of conserving viable and representative samples of all plant associations and plant species (particularly those that are rare or threatened) not yet adequately protected in New South Wales, priorities need to be set. It is suggested that the most threatened and poorly conserved plant associations be surveyed and viable samples reserved and managed sympathetically. For rare or threatened plant species, those that are most threatened and most distinct in the taxonomic sense should be given special emphasis in protection strategies. Some plant species and plant associations will require more detailed ecological research if they are to survive. Others may only require passive management and monitoring, particularly regarding the effects of different fire regimes and nutrient cycles.

There is still the opportunity to improve the conservation of the flora of New South Wales as, (unlike some other parts of the world), viable natural areas remain. An integrated approach is necessary, involving rational land-use decisions by government, protection of remnant vegetation through planning controls, reservation of important sites, taxonomic research, monitoring and ecological research.

While plant taxonomy has been given impetus by the *Flora of Australia* series, Parsons & Scarlett (1989) demonstrate that some genera are being much more extensively examined than others. The *Flora*, working to tight deadlines, leaves a proportion of taxonomic problems unresolved. That presents a deficiency in information needed for conservation programs.

Table 7. Number of rare or threatened plant species for major biogeographical habitat-provinces in NSW (from Benson 1989).

Habitat - Provinces	Risk Codes Extinct (X)	Endangered (E)				Vulnerable (V)				Rare (R)				Unknown Status (K)				Risk Code Totals					Total X+E+V +R+K=
		N	Ci	C-	Ca	N	Ci	C-	Ca	N	Ci	C-	Ca	N	Ci	C-	Ca	N	Ci	C-	Ca	TC	
Rainforest (All types)	1	9	7	4	0	1	3	11	1	0	6	18	17	2	0	0	0	12	16	33	18	67	80
Alpine (above treeline - Kosciusko NP)	0	0	0	0	0	0	0	3	1	0	0	17	13	0	0	1	0	0	0	21	14	35	35
Forests, heaths and swamps of high altitudes - tablelands	8	8	3	1	1	19	13	19	4	8	6	65	33	1	0	2	0	36	22	87	38	147	191
Forests, heath and swamps of lowland coastal zones	7	12	4	2	0	14	12	18	5	8	5	44	25	3	1	6	0	35	22	70	30	122	164
Forests, woodlands grasslands of western slopes & eastern plains (Central Division)	6	0	0	2	0	11	1	6	3	0	2	8	2	2	0	1	0	13	3	17	5	25	44
Semi-arid shrublands woodlands, grasslands, swamps of the western plains mainly Western Division	5	1	4	0	0	17	2	0	2	1	0	1	3	4	0	3	0	22	6	4	5	15	43
Total	27	30	18	9	1	62	31	57	16	15	19	153	93	12	1	13	0	119	68	232	92	411	557

For explanation of risk codes see Briggs and Leigh (1988)

Ci = inadequately conserved ie. less than 1000 individuals located in conservation reserves
Ca = adequately conserved ie. 1000 or more individuals located in conservation reserves
C- = known to be in reserve(s) but adequacy unknown
N = not known from any conservation reserves

Conservation reserves include all reserves managed by the NSW NPWS & Flora Reserves managed by the NSW Forestry Commission.

Note: These figures were derived by the allocation of species to one or more habitat - provinces depending on their distribution. In most cases species are restricted to only one habitat - province. Nevertheless the fact that some species are located in more than one habitat - province explains the inflated total figure of 557 compared to the figure for the number of rare or threatened plants listed for NSW which is 532. Species extinct in NSW but extant in other states are ignored. For example 10 species which once existed on the western plains now only occur in other states.

Some ecological research is now attempting to investigate some of the processes that can lead to the extinction of species (besides the obvious ones such as direct destruction through clearing the land). One aim is to extrapolate the results of studying functional groups and universal factors such as fire to a range of other species and associations of species. In addition to this type of research there remains the special need to investigate the population dynamics of threatened plant species that have been assessed as having declining populations. Also, research into the genetic variation within and between populations can play a major role in conserving species with small populations (Moran & Hopper 1983; Sampson et al. 1989).

I suggest that additional research into and application of biological control of 'environmental weeds' would, over the long term, be most beneficial (and cost-effective) for many native plant associations and species.

Until we gain more knowledge of our flora conservation decisions will continue to be based on 'qualified' subjectivity, particularly in choosing reserves and managing them. To conserve the flora of New South Wales, we will need more effective controls over excessive clearing of vegetation, river diversion and other developments. This can be achieved through more effective use of soil conservation, planning and wildlife protection legislation, and these need to be improved. The current growth of 'Land Care' in rural regions is encouraging, but the past losses of native vegetation have been so great that this may not be enough. Within the next 10 years most of the State's remaining tall old growth forests may be logged, much of the remnant vegetation on the Western Slopes will be further degraded and extensive clearing of the central and north-eastern sections of the Western Division may continue. Prevention of the continued widespread destruction of vegetation and the consequent loss of species will continue to depend on educating the public and its institutions about ecology and conservation, but it would also benefit by the enactment of improved legislation to protect habitats and the enforcement of all the relevent laws affecting nature conservation.

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Bryophytes in the vicinity of Jenolan Caves, New South Wales

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Abstract

Downing, A.J.[1]*, Ramsay, H.P.*[1] *& Schofield, W.B.*[2] *(*[1] *School of Biological Sciences, Macquarie University, Sydney, NSW, Australia 2109;* [2] *Department of Botany, University of British Columbia, Vancouver, B.C., V6G 2B1, Canada) 1991. Bryophytes in the vicinity of Jenolan Caves, New South Wales* Cunninghamia *2(3): 371–384.* A total of 115 bryophytes (96 mosses in 56 genera, 18 hepatics in 12 genera, and one anthocerote) were collected from eight localities in the vicinity of Jenolan Caves, and two localities at Kanangra Walls in the Central Tablelands of NSW Geology, vegetation, climate and European settlement appear to influence distribution of bryophytes within the Jenolan Caves Reserve. The species list includes 5 new records of mosses for New South Wales and 18 additions to the mosses of the Central Tablelands. The bryophyte assemblage on limestone at Jenolan Caves is unique and distinctive, and many species present on limestone at Jenolan are either not present or not common on the sandstones and shales of the nearby Blue Mountains plateau.

Introduction

The Jenolan Caves are located in an elongated body of limestone in the Jenolan River Valley in the Great Dividing Range, 110 km west of Sydney and 30 km south-west of Katoomba, NSW (33°47'S, 150°05'E) (Figure 1). The blue-grey cliffs of Jenolan Caves Limestone form a massive barrier across the bottom of the valley, 790 metres above sea level. Three streams meet at a point below the Grand Arch (Figure 2) and flow eastward as the Jenolan River. Surveyors Creek flows from the south-west, and has cut through the limestone ridge to form the Grand Arch. Two streams, McKeowns Creek from the north, and Camp Creek from the south flow through the limestone, each creating a complex system of caverns for approximately 1 km on each side of the Grand Arch (Dunlop 1967). The Jenolan River runs through a young, steep-sided, v-shaped valley cut into the eastern side of the Great Dividing Range.

The main body of limestone at Jenolan is an ancient, Upper Silurian coral reef, composed of quite pure fossiliferous limestone, 96% to 99% calcium carbonate. Limestone lenses interbedded with shale are found 1.5 km to the east of Jenolan Caves (Chalker 1970).

The western valley sides are steep slopes derived from chert, with a spilite intrusion in the vicinity of Caves House. To the east a sequence of sediments and volcanics includes shales, pyroclastic rocks, cherts, tuffs, quartzite, sandstone and shaley limestone (McClean 1983). Alluvial deposits can be found in the valleys of McKeowns Creek and Camp Creek.

Climate at Jenolan Caves tends to be more extreme than that of Katoomba and the surrounding Upper Blue Mountains. Summer temperatures can exceed 40°C while winter temperatures can fall as low as -10°C. Temperatures on the plateau top are approximately 2°C to 3°C cooler than temperatures at the caves. Heavy snowfalls are not unusual in winter. Rainfall is evenly distributed throughout the year and ranges from 960 mm per annum at the Caves (790 metres a.s.l) to 1150 mm per annum on the plateau top at Jenolan State Forest, 1158 metres a.s.l (Bureau of Meteorology 1979).

Vegetation

Montane moist forest occurs at higher altitudes on moist, fertile, relatively deep clay and sandy loams. This open-forest is characterised by *Eucalyptus fastigata* and *Eucalyptus dalrympleana* subsp. *dalrympleana* occasionally with *Eucalyptus viminalis* and *Eucalyptus radiata* subsp. *radiata. Eucalyptus* woodland occurs on steep slopes, narrow ridges and gullies on quartzites, shales, cherts and tuffs. Characteristic species include *Eucalyptus fibrosa, Eucalyptus crebra, Eucalyptus eugenioides* and *Eucalyptus punctata* (Keith & Benson 1988).

Trees on shales in the immediate vicinity of the Grand Arch include *Eucalyptus punctata, Eucalyptus dives, Eucalyptus eugenioides* and *Eucalyptus radiata* subsp. *radiata.* Understory shrubs include *Bursaria spinosa, Oxylobium ilicifolium, Lissanthe strigosa, Persoonia linearis* and *Acacia falciformis.*

Vegetation on the limestone is relatively sparse *Poa* grassland, with scattered trees and shrubs. This contrasts sharply with shale, chert, rhyolite and tuff valley sides which are heavily wooded with little grass cover. Trees found on limestone include *Eucalyptus viminalis, Brachychiton populneus* (Kurrajong), *Acacia melanoxylon,* and *Ficus rubiginosa.* Shrubs on the limestones include *Acacia falciformis, Dodonaea viscosa, Swainsona galegifolia* and *Citriobatus multiflorus.* Climbing plants are more numerous on the limestones and include *Clematis aristata* and *Hardenbergia violacea.* Herbs include grasses (*Poa* spp., *Themeda australis*) and ferns (*Adiantum aethiopicum*). *Urtica incisa* (Stinging Nettle) is abundant in the vicinity of Caves House. Many exotic species, including *Rhododendron,* flowering cherries and roses have been planted in the gardens of the Caves House Hotel. Weeds and garden plants that have escaped from the gardens to invade the surrounding hillsides, include *Acer pseudoplatanus, Pinus radiata,* (Monterey pine), *Lunaria* (Honesty) and *Hypericum perforatum* (St. John's wort).

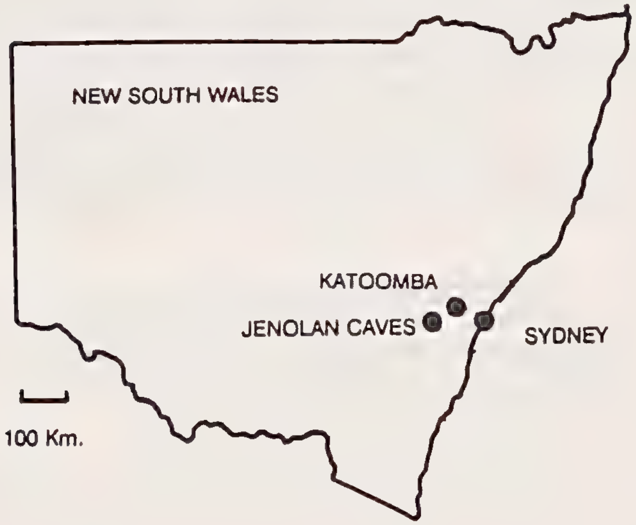

Figure 1. New South Wales showing location of Jenolan Caves.

Previous bryophyte collections from Jenolan Caves.

In the late 1890s, bryophytes were collected at Jenolan Caves by W. J. Blakely, J. H. Maiden, H. Malthouse and W. Forsyth. Among the earliest collections at the New South Wales National Herbarium are *Papillaria flavolimbata* (C. Muell. & Hampe) Jaeg. collected by H. Malthouse 572 (as *Papillaria cerina* (Hook. f. & Wils.) Par.) in August, 1898, *Tortula antarctica* (as *Tortula princeps*) J.H. Maiden (1898) 45, 368, Blakely (Oct 1899) 367, 476. Blakely collected *Thuidium sparsum* (as *Thuidium suberectum*) and *Papillaria amblyacis* (C. Muell.) Jaeg. (as *Meteorium amblyacis* (C.Muell.) Mitt. in June, 1899 (refer also to Watts & Whitelegge 1902, 1905). The National Herbarium (NSW) holds 28 mosses and 3 hepatics recorded as having been collected from Jenolan Caves (see Tables 1 & 2).

In 1901, W. J. Blakely, a gardener at Jenolan Caves and J. C. Wiburd, a guide for many years and caretaker from 1903 to 1932, published *A List of Plants Collected in the Vicinity of Jenolan Caves* (Blakely & Wiburd 1901). Included in the introduction by J. H. Maiden is the note 'Mr. W. Forsyth has the mosses in hand and a list of this and of other groups of plants not yet included in this preliminary Florula, may be expected in due course'. Unfortunately this list was never published and we have been unable to find the the manuscript of this list or the specimens on which it was based.

There are no detailed studies of bryophyte distribution on limestones in NSW, and indeed few published bryophyte species lists for particular localities (see Ramsay, Downing & Schofield 1990). This study was undertaken to determine the bryophyte species which occur on and in the vicinity of the Jenolan Caves limestone.

Results

Bryophytes were collected from numerous sites in the vicinity of Jenolan Caves during a number of field trips between October 1987 and December 1989. Collecting sites have been grouped into ten localities, eight in the vicinity of Jenolan Caves (Figure 2) and two in the vicinity of Kanangra Walls (Figure 3). Identifications were based on Sainsbury (1955), Scott & Stone (1976), Catcheside (1980), Scott (1985) and some more recent revisions of specific taxa including *Campylopus* (Frahm 1987) *Hypnum* (Ando 1982), *Orthotrichum* (Lewinsky 1984), *Macrocoma* and *Macromitrium* (Vitt & Ramsay 1985), *Mielichhoferia* (Shaw 1985), *Tortula* (Kramer 1988), *Thuidium* (Touw & van Haak 1990) and *Papillaria* (Streimann 1991). Reference was also made to Scott & Bradshaw (1986) for hepatics, and Streimann & Curnow (1989) for mosses.

A total of 115 bryophytes including 96 species of mosses (56 genera), 18 species of hepatics (12 genera) and one anthocerote were recorded (Tables 1 & 2) from the 10 localities. Results were based on 336 collections of mosses and 40 collections of hepatics including some earlier collections of H.P. Ramsay and D.G. Catcheside. Voucher specimens of all species collected will be deposited at the National Herbarium *(NSW)* for future reference and lists (as Appendices 1 & 2) will be held in the Royal Botanic Gardens Library for reference.

Details of the collecting localities are as follows; 1. *Binoomea Ridge Road* [BRR] (Figures 2, 4b): consists of steep hillside slopes, roadside cuttings and embankments of the Hampden – Jenolan Caves Road. Collections were made from the top of the plateau to Inspiration Point Lookout just above the Jenolan River. Subtrata include shales, cherts, tuffs, quartzite and sandstones. Vegetation consists of *Eucalyptus* woodland with grasses (*Poa* spp.), herbs, low shrubs and climbing plants such as *Clematis aristata* and *Hardenbergia violacea.*

Table 1. Mosses collected in the vicinity of Jenolan Caves, N.S.W. (see text for locality descriptions).

Taxon	**1 BRR**	**2 BP**	**3 GAE**	**4 MCV**	**5 GAW**	**6 CA**	**7 SFT**	**8 OH**	**9 KW**	**10 BRC**
+*Amphidium cyathicarpum*						L				
+*Anoectangium bellii*						L				
Atrichum androgynum	x									
Barbula crinita				x	x	x				
+*Barbula luteola*						L				
+*Barbula unguiculata*	x			x		x				
**Bartramia papillata*	x			x				x		
+*Brachymenium preissianum*						L				
**Brachythecium rutabulum*	x		x	x		x	x			
+*Brachythecium salebrosum*	x				x	x				
**Breutelia affinis*	x		x				x	x		
Bryum argenteum			x		x	x				
Bryum billardieri	x					x	x	x		
Bryum campylothecium						x	x			
**Bryum capillare*	x					x				
Bryum clavatum (*B. erythrocarpoides*)						x		x		
Bryum dichotomum						L				
Bryum creberrimum	x				x					
Bryum pseudotriquetrum	x					x		x		
+*Bryum rubens*							x			
Bryum torquescens					x	x				
+*Bryum sp. nov.*			x							
Campylopus clavatus					x				x	x
+*Campylopus incrassatus*					x	x				
Campylopus introflexus	x		x	x			x		x	
**Ceratodon purpureus*	x			x		x		x	x	
Conostomum pusillum										x
Dawsonia longiseta			x							
Desmatodon convolutus					x	x				
+*Desmatodon recurvatus*					x					
Dicnemoloma pallidum	x		x				x			x
Didymodon torquatus				x						
Ditrichum difficile	x		x					x	x	
**Encalypta vulgaris*			L		L	L				
Fabronia australis						x	x			
+*Fabronia scottiae*						x				
Fissidens asplenioides					x					
Fissidens humilis						L				
**Fissidens leptocladus*			x	x	x	x				
Fissidens pungens						L				
Fissidens rigidulus		x								
**Fissidens taylorii*			L	L						
Fissidens vittatus	x		x	x		x				
Funaria apophysata					x					
Funaria glabra			L			L				
**Funaria hygrometrica*				x					x	
Gigaspermum repens			L	L		L				
Grimmia laevigata						L				
Grimmia pulvinata var. *africana*	x		x	x	x	x	x			
Grimmia trichophylla								x		
Gymnostomum aeruginosum	x		x			x				
Hedwigia ciliata	x		x			x	x			
Hedwigidium integrifolium							x			

Taxon	**1** **BRR**	**2** **BP**	**3** **GAE**	**4** **MCV**	**5** **GAW**	**6** **CA**	**7** **SFT**	**8** **OH**	**9** **KW**	**10** **BRC**
Hypnum cupressiforme var. *cupressiforme*						x	x	x		
+*Hypnum cupressiforme* var. *lacunosum*						L				
Hypopterygium rotulatum				L						
Lembophyllum divulsum				L		L				
**Leptodon smithii*			L	L		L				
Lopidium concinnum						L				
Macrocoma tenue subsp. *tenue*	x			x						
Orthodontium lineare	x									
Orthotrichum assimile	x				x	x				
Orthotrichum cupulatum var. *cupulatum*			L	L	L	L				
Papillaria crocea				x	x	x				
**Papillaria flexicaulis*			L	L	L	L				
Philonotis scabrifolia	x									
Philonotis tenuis	x									
+*Plagiomnium novaezealandiae*				L						
Pohlia nutans									x	
**Polytrichum juniperinum*	x		x							x
Pottia truncata						x				
Pseudoleskeopsis imbricata			L	L	L	L				
Ptychomitrium australe			x	x		x	x			
Racomitrium crispulum								x		
+*Racomitrium lanuginosum* var. *pruinosum*										x
Racopilum cuspidigerum var. *cuspidigerum*				x	x	x				
Rhacocarpus purpurascens										x
Rhaphidorrhynchium amoenum				x						
**Rhyncostegium tenuifolium*	x		x			x				
**Schistidium apocarpum*	x		x		x	x				
Schizomenium bryoides (*Mielichhoferia bryoides*)	x					x				
**Tayloria octoblepharis*									x	
**Thuidium cymbifolium*				L		L				
+*Thuidium sparsum*	x		x	x	x	x	x			
+*Tortella cirrhata*			L							
+*Tortella dakinii*					L					
**Tortula antarctica* (*T. princeps*)	x			x	x	x	x			
Tortula muralis			L		L	L				
Tortula norvegica				L						
Tortula pagorum					x	x	x			
Tortula papillosa				x		x	x			
+*Trichostomum brachydontium*			x	x		x	x			
Triquetrella papillata	x			x		x				
**Weissia controversa*	x		x		x	x				
Weissia controversa var. *gymnostoma*						L				
Zygodon intermedius						L				
Total	**31**	**1**	**30**	**32**	**27**	**59**	**18**	**10**	**7**	**6**

* = species collected at Jenolan Caves prior to 1987.
+ = additions to the species listed for Central Tablelands in Ramsay (1984).
L = occurred exclusively on limestone.
Species underlined = New records for N.S.W.

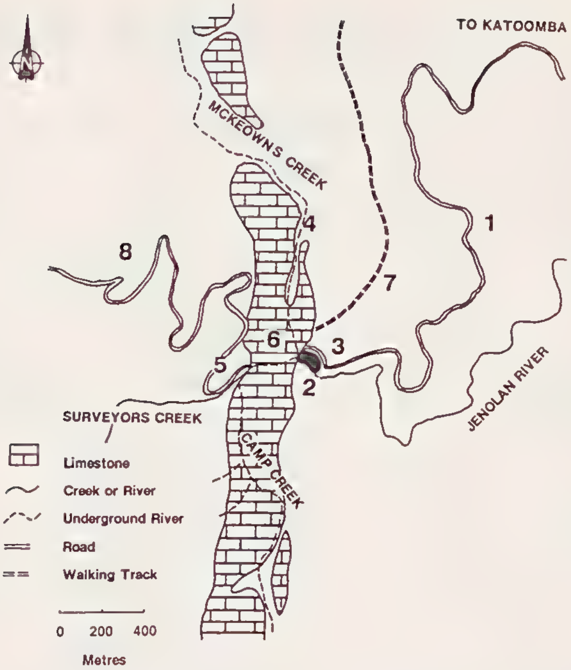

Figure 2. Jenolan Caves, NSW showing the location of collecting sites and limestone outcrops. Adapted from McClean, 1983. **1.** Binoomea Ridge Road, **2.** Blue Pool, **3.** Grand Arch East, **4.** McKeowns Valley, **5.** Grand Arch West, **6.** Carlotta Arch, **7.** Six Foot Track, **8.** Oberon Hill.

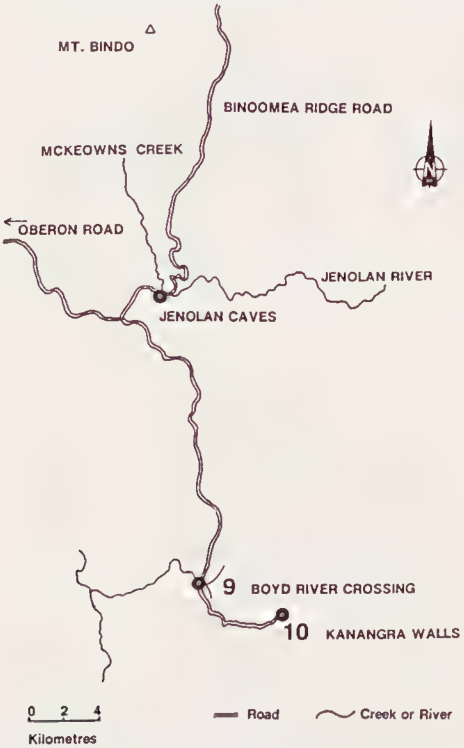

Figure 3. Collecting sites in the vicinity of Jenolan Caves.

Thirty nine species (31 mosses, 8 hepatics) were recorded along Binoomea Ridge Road. Most species collected along the road are relatively common on the sandstones and shales of the Blue Mountains. Two exceptions are *Philonotis scabrifolia* and *Atrichum androgynum*. Few epiphytes were collected, but more hepatics (8) were collected here than from any other locality.

2. *Blue Pool.* [BP] (Figure 2, 4a&b): an artificially created lake on the eastern side of the Grand Arch. The only bryophyte collected, *Fissidens rigidulus*, was growing under water, at 1.5 metres below the surface on a large, rounded, non-limestone cobble.

3. *Grand Arch East* [GAE] (Figure 2, 4a): covers the area on the eastern side of the Grand Arch, excluding the Blue Pool. Substrata include shale, limestone and rhyolite porphyry. Vegetation consists of *Eucalyptus* woodland on the lower hillsides, with *Ficus rubiginosa* on limestone outcrops, and taller eucalypts and tree ferns in moist and shaded positions.

Thirty three bryophytes (30 mosses and 3 hepatics) were recorded from this sheltered location where they are abundant on vertical, roadside rock walls, both on shale and limestone. Epilithic mosses (in particular *Orthotrichum cupulatum* subsp. *cupulatum*, *Grimmia pulvinata* and *Schistidium apocarpum*) and lichens are also abundant on the stone masonry of roadside walls. *Dawsonia longiseta* and *Reboulia hemisphaerica* were both collected from damp sand at the edge of a roadside drain below a shale rock wall. *Leptodon smithii* was collected from moist and shaded limestone boulders near the entrance to the Devils Coach House.

4. *McKeowns Valley* [MCV] (Figures 2, 5a–d): a narrow, canyon-like, limestone gully on the northern side of the Grand Arch, entered via the Devils Coach House (Figure 3). Grasses and shrubs predominate, with occasional trees of *Eucalyptus viminalis* and *Acacia melanoxylon*.

Thirty eight species (32 mosses, 6 hepatics) were collected in the valley where they obviously thrive in cool, moist and sheltered conditions. Epiphytic bryophytes, in particular, *Papillaria* spp., *Frullania* spp. and *Macrocoma tenue* subsp. *tenue* festoon the branches of shrubs and fallen logs.

One species of particular interest was *Plagiomnium novaezealandiae* which grows in luxuriant mats in seepages over rock. This species has not been reported previously from the Central Tablelands of NSW (Ramsay 1984). *Gigaspermum repens*, a species common in arid and semi arid areas of western New South Wales, occurs on soil in crevices in and between rocks.

5. *Grand Arch West* [GAW] (Figures 2, 4c): covers the western side of the Grand Arch, including Jenolan Caves House (gardens and stone walls) and the No. 1 carpark. Substrata include spilite and limestone. This sheltered position contains many exotic trees, shrubs, and introduced weed species. *Poa* grassland is present on the limestone at the rear of the hotel. Construction of buildings, roads, gardens and car parks has caused significant changes to the natural vegetation.

Thirty three species (27 mosses, 1 anthocerote, 5 hepatics) were collected on the western side of the Grand Arch. *Encalypta vulgaris*, a calcicolous moss, is present on damp rock on the western wall of the Grand Arch, and on limestone walls of the gardens. *Targionia lorbeeriana*, a thallose hepatic which we have not previously collected in the Blue Mountains, grows on damp soil in sheltered locations in the Jenolan Caves House garden, and under the shelter of overhanging vegetation along trackside embankments. *Anthoceros laevis*, an anthocerote, was also collected from similar environments. *Tortula antarctica* (*T. princeps*) and *Barbula crinita* are common on soil in the garden. *Marchantia polymorpha*, a thallose hepatic and *Bryum*

Table 2. Hepatics and anthercerote collected in the vicinity of Jenolan Caves, NSW (see text for locality descriptions).

Taxon	**1** **BRR**	**2** **BP**	**3** **GAE**	**4** **MCV**	**5** **GAW**	**6** **CA**	**7** **SFT**	**8** **OH**	**9** **KW**	**10** **BRC**
#*Anthoceros laevis*					x	x				
Asterella drummondii						L				
Cephaloziella exiliflora	x			x			x			
Chiloscyphus semiteres	x							x		
Fossombronia wondraczekii	x									
Frullania falciloba	x			x	x	x				
Frullania pentapleura				x		x				
Frullania probosciphora	x			x		x				
Frullania squarrulosa							x			
Lophocolea biciliata	x				x					
Lophocolea bidentata	x		x							
Lophocolea novae-zeelandiae					x					
Lunularia cruciata	x									
**Marchantia polymorpha* var. *aquatica*					x					
Metzgeria decipiens			x							
Metzgeria furcata						x				
**Porella crawfordii*				x						
Reboulia hemisphaerica			x							
Targionia lorbeeriana				x	x					
Total	**8**	**0**	**3**	**6**	**6**	**6**	**2**	**1**		

* = species collected at Jenolan Caves prior to 1987.
L = species collected exclusively on limestone.
# = anthocerote.

argenteum, a small, tufted moss, are two cosmopolitan bryophytes collected from the vicinity of Jenolan Caves House and the No. 1 carpark.

6. *Carlotta Arch* [CA] (Figure 2, 4a): includes exposed sites on limestone in the vicinity of the Carlotta Arch and the No. 2 carpark. Vegetation on limestone near the arch is sparse and dominated by shrubs, grasses and climbing plants. In the vicinity of the No. 2 carpark the area includes a number of rock outcrops sheltered by tall trees including *Eucalyptus globulus* subsp. *bicostata* and *Eucalyptus viminalis*.

Sixty five species (59 mosses, 5 hepatices, 1 anthocerote) were collected in the vicinity of the Carlotta Arch and the No. 2 Carpark. Of particular interest was *Gymnostomum aeruginosum*, a calcicolous species often associated with bat guano, growing in damp limestone dust in a small cave bordering the Carlotta Arch. Three of the hepatics (*Frullania* spp.) are epiphytic on *Bursaria spinosa*. One thallose hepatic, *Asterella drummondii*, and the anthocerote *Anthoceros laevis* both grow on the damp soil of a trackside bank, protected by overhanging *Poa* grass tufts. Epilithic mosses such as *Pseudoleskeopsis imbricata*, *Orthotrichum cupulatum* var. *cupulatum*, *Grimmia pulvinata* are abundant.

7. *Six Foot Track* [SFT] (Figure 2): a track in a shale band on the steep valley sides to the east of the Devils Coach House. Vegetation consists of *Eucalyptus* woodland, with occasional shrubs. Much of the ground is covered in thin plates of shattered rock. Lichens are abundant on exposed, flaking boulders.

Table 3. Bryophytes recorded at the National Herbarium of NSW as having been collected from Jenolan Caves prior to 1987 but not collected in the course of this study.

1. *Breutelia pendula* (probably incorrect identification)
2. *Dicranoloma dicarpum*
3. *Hypnodendron vitiense*
4. *Leptotheca gaudichaudii*
5. *Papillaria amblyacis*
6. *Papillaria flavo-limbata*
7. *Pyrrhobryum parramattense*
8. *Wijkia extenuata*
9. *Symphyogyna interrupta*

Twenty bryophytes (18 mosses and 2 hepatics) were collected from shales along the Six Foot Track. *Hedwigidium integrifolium* and *Hedwigia ciliata* are both common on rock, together with dense patches of lichens. *Campylopus introflexus* is most conspicuous on the ground, growing on charcoal and on soil between rock fragments.

8. *Oberon Hill* [OH] (Figure 2): consists of sheltered roadside embankments of the steep hillside on the western side of McKeowns Valley, along the Oberon Road. Moist montane forest has a dense cover of grasses (including *Poa* spp.) and herbs. There are very few rock outcrops and very little exposed soil.

Eleven species were collected on the Oberon Hill (10 mosses, 1 hepatic). Bryophytes were collected from exposed roadside embankments. We have not previously collected *Grimmia trichophylla* in the Blue Mountains and it is rare in the Central Tablelands (Ramsay 1984). Although *Racomitrium crispulum* is common in the vicinity of Megalong Valley, we have found it only at this site in the Jenolan area.

9. *Kanangra Walls Lookout* [KW] (Figure 3): the exposed sandstone plateau overlooking Kanangra Walls.

Seven mosses (no hepatics) were collected from the sandy soils of the Kanangra Walls Lookout. Most grow in compacted sandy soil by the side of walking tracks. Three species, *Funaria hygrometrica, Pohlia nutans* and *Tayloria octoblepharis* were collected at Kanangra Walls but were not collected from any of the Jenolan Caves sites although all three species are common on sandstones and shales in the Blue Mountains.

10. *Boyd River Crossing* [BRC] (Figure 3): an area of *Eucalyptus* woodland and heath on granite, approximately 7 km north of the Kanangra Walls Lookout.

Six mosses were collected from the Boyd River Crossing. Bryophytes and lichens are abundant in and around heath plants on a large area of exposed granite moist with seepage. Two species, *Conostomum pusillum* and *Racomitrium lanuginosum* var. *pruinosum* were not collected in the immediate vicinity of Jenolan Caves, and we have not previously collected *Racomitrium lanuginosum* var. *pruinosum* in the Blue Mountains area. *Racocarpus purpurascens* was collected from an exposed boulder in *Eucalyptus* woodland adjoining the heath. This species is common in the Blue Mountains area on sandstone, but was not collected from any other site at Jenolan during this study.

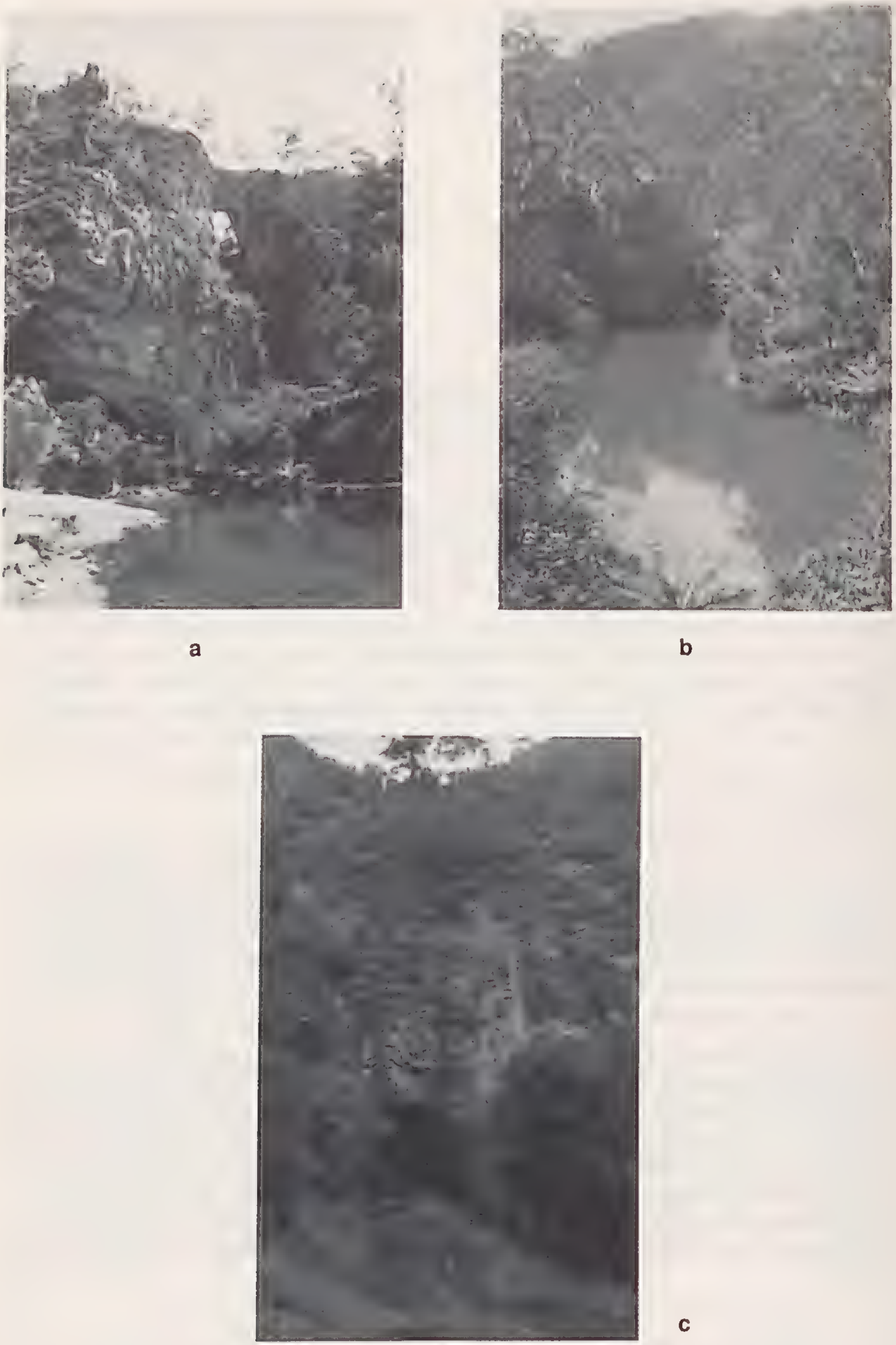

Figure 4. Jenolan Caves area. **a.** Blue Pool, Grand Arch and Carlotta Arch. **b.** Blue Pool, and *Eucalyptus* woodland typical of vegetation along Binoomea Ridge Road. **c.** Grand Arch, western face.

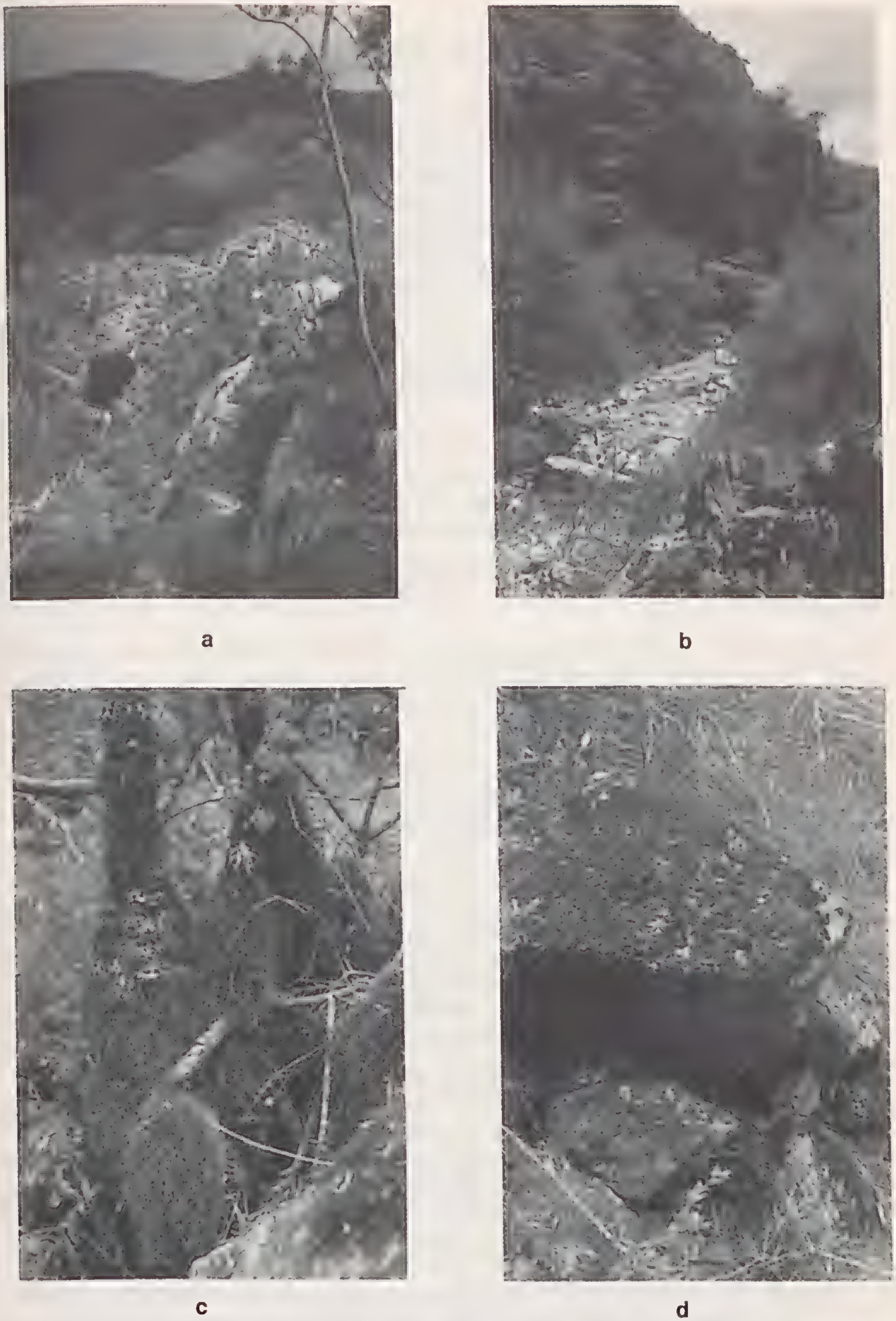

Figure 5. McKeowns Valley. **a.** McKeowns Valley leading to the Devils Coach House viewed from Oberon Hill. **b.** Limestone outcrops along the dry creek bed of McKeowns Valley. **c.** Mosses (*Papillaria* spp.) festooning bases of shrubs in McKeowns Valley. **d.** Mosses *(Orthotrichum cupulatum* var. *capulatum, Tortula antarctica* and *Grimmia pulvinata* growing in abundance on limestone boulders in McKeowns Creek Valley.

Discussion

More bryophyte species were recorded from localities that included limestone (Grand Arch East, McKeowns Valley, Grand Arch West and Carlotta Arch) than from localities based on non-limestone substrata (Binoomea Ridge Road, Six Foot Track, Oberon Hill, Kanangra Walls and Boyd River Crossing) (Tables 1 & 2). In the Jenolan Caves area twenty eight species (27 mosses and 1 hepatic) were recorded exclusively from limestone substrata. (Tables 1 & 2). However, not all species recorded only from limestone at Jenolan are exclusively calcicolous e.g. *Leptodon smithii* occurs as an epiphyte on the trunks of trees and *Hypopterygium rotulatum* and *Lopidium concinnum* can be found on a variety of substrata in closed forests of the Blue Mountains. None of the species collected from limestone is endemic to Australia. Some species such as *Encalypta vulgaris* and *Amphidium cyathicarpum* are widespread, while others such as *Pseudoleskeopsis imbricata* and *Orthotrichum cupulatum var cupulatum* are restricted to Australia and New Zealand.

Three moss families (Pottiaceae, Bryaceae, Fissidentaceae) were well represented. From the Pottiaceae, 16 species in 9 genera (*Anoectangium, Barbula, Desmatodon, Didymodon, Pottia, Tortella, Tortula, Weissia and Trichostomum*) were collected. From the Bryaceae 16 species in 4 genera, (*Brachymenium, Bryum, Orthodontium, Pohlia*) were collected. More species of *Bryum* (12, including one undescribed species) were collected than of any other genus. From the Fissidentaceae, 7 species of *Fissidens* were collected.

Five species are reported as new records for NSW (*Anoectangium bellii, Bryum rubens, Bryum* sp. nov., *Tortella dakinii, Trichostomum brachydontium*) and eighteen species (Tables 1& 2) have been added to the list for the Central Tablelands of NSW (Ramsay 1984, Ramsay et al. 1990).

Twenty two of the 31 bryophytes previously collected at Jenolan Caves and held at the National Herbarium (NSW) were re-collected during this study (Tables 1, 2). We suggest the following possible explanations for the absence of 9 previously collected species from our collections:

a. Identification of one species is probably incorrect (Table 3).

b. Human influence has caused changes to habitat that may have affected bryophyte distributions. Construction of the bridge over McKeowns Creek and the damming of the Jenolan River valley downstream from the Grand Arch have produced the Blue Pool. Rampant weed growth on the western side of the Grand Arch may also have changed the nature of bryophyte assemblages. These changes may also have produced habitats suitable for colonisation by exotic bryophyte species, e.g. *Lunularia cruciata, Marchantia polymorpha* var. *aquatica.*

c. It is possible that some specimens were collected from sites outside our selected study area and lumped together under the name Jenolan Caves. Most of the species not collected in our survey are species which would be common in sheltered gullies in moist closed-forest e.g. in Megalong Valley (*Pyrrhobryum parramattense, Dicranoloma dicarpum, Wijkia extenuata, Papillaria amblyacis, Papillaria flavolimbata*) rather than on exposed rocky outcrops in *Eucalyptus* woodland of the Jenolan Caves area today. In the late 1880s the Six Foot Track was surveyed from Katoomba, through Nellies Glen, Megalong Creek, Coxs River, Little River and over Black Range to Jenolan Caves (Smith 1984). It seems likely that in the late 1890s, botanists such as Maiden and Blakely would have travelled to Jenolan via the Six Foot Track and that some of the collections listed here may have been from the closed-forests of Megalong Valley near the start of the journey to Jenolan Caves.

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Sex ratios in dioecious Australian grasses: a preliminary assessment

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Abstract

Connor, H.E.[1] & Jacobs, S.W.L.[2] ([1] Centre for Resource Management, University of Canterbury, Christchurch, New Zealand; [2] National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia 2000) 1991. Sex ratios in dioecious Australian grasses: a preliminary assessment. Cunninghamia *2(3): 385–390.* Four grass genera in Australia are dioecious: *Spinifex, Zygochloa, Pseudochaetochloa* and *Distichlis*. In three genera the sex ratio equals or approximates the primary sex ratio of 1M:1F but in *Distichlis* the populations at most sites consist exclusively of female plants. Australia offers the best opportunity in the Old World to collect in nature basic information to advance knowledge of dioecism in the Poaceae. This preliminary assessment is intended to generate interest in that topic.

Introduction

The primary sex ratio males:females = 1 was established by Fisher (1930) and the theory was extended by Shaw & Mohler (1953). A recent re-examination of the topic is that of Bull & Charnov (1988). For dioecious plants data on sex-form frequencies are derived from counts in natural populations or from genetic experiments. Because of the scarcity of sex-form frequency data in the grasses, Connor (1987) advocated their collection to help substantiate current theories or substitute for them. In Australia four genera of grasses are dioecious: *Spinifex*, three species, and *Zygochloa*, monotypic (Spinificinae, Paniceae); *Pseudochaetochloa*, monotypic (Cenchrinae, Paniceae), and *Distichlis*, one species (Monanthochloinae, Eragrostideae). This is the highest concentration of dioecious grass genera in the Old World; in the New World about 20 genera are dioecious with at least 16 of them present in Mexico.

In Australia sex-form frequencies are known for *Spinifex hirsutus* and *S. sericeus* (Kirby 1988; McDonald 1983; Maze & Whalley 1990a). Here we report those for *S. longifolius*, and for *Distichlis*, *Pseudochaetochloa*, and *Zygochloa*. Three conform to 1M:1F; the exception is *Distichlis distichophylla* where females alone are found at many sites in Victoria. None of these results assists in the formulation of better models describing sex ratios in wind-pollinated dioecious plants.

Methods

Populations of four of the six Australian dioecious grass species were examined in New South Wales, Victoria, and Western Australia (Tables 1 & 2).

As all species were at anthesis, or nearly so, sex-forms and their frequencies were determined by inspection of single plants (genets) along transects whose lengths were determined by the size of the population. *Pseudochaetochloa* frequency was determined in a rectangular quadrat.

In *Distichlis* two other counts were made at most sites: (i) the number of spikelets in 10 inflorescences of the sex-form, and (ii) the number of florets per spikelet in the penultimate spikelets of five inflorescences. These allow an estimate to be made of differences in resource investment at an early stage of the reproductive cycle.

Results

Distichlis distichophylla (Labill.) Fassett

This short, rhizomatous grass tends to form long narrow strips. In Victoria and New South Wales it was at anthesis at all sites in early December 1987. Stigmas in females are purple, up to 5 mm long, and emerge from the apex of a very slightly opened floret; the sterile anthers, c. 0.1 mm long on filaments up to 2 mm long, are not exserted. In male flowers, tailed anthers c. 3 mm long are borne on filaments c. 4 mm long, but the stigma-styles, c. 2 mm long, are not evidently exserted.

Sex-form frequencies were collected from nine sites, all but one in Victoria (Table 1). At two localities, both male and female plants were found together; everywhere else all populations consisted of female plants only. On the flat, salt-marsh margin of the Betka River, Malacoota, Victoria, one population was exclusively female, but a second, some 50 m upstream, contained 20M and 2F. Ecological differences could not be detected that would account for such a major change.

At Lake Tyer's Boat Ramp No. 2, Victoria, there were six colonies, three of each sex, and judging from their lengths (M = 50 m, 15 m, 5 m; F = 50 m, 5 m, 5 m) they probably represented an initial migration of both sex-forms followed by fragmentation into the present subpopulations. Mixed through one female patch were occasional small male plants. This is the only site at which both sex-forms are present in something approaching 1M:1F.

Exclusively female populations were found at four localities; the sole population exclusively of male plants was found at Lakes Entrance, Victoria.

The mean numbers of spikelets per inflorescence and florets per spikelet are not significantly different between sex-forms in *D. distichophylla* (Table 1).

Spinifex longifolius R. Br.

This Western Australian stoloniferous plant of coastal sand dunes was at pre-anthesis in early June 1988 at Cable Beach. Female inflorescences are globular heads, about 20 cm in diameter, of sessile racemes reduced to a single spikelet on a stout bristle 5–10 cm long. Male inflorescences are terminal clusters of racemes of two-flowered spikelets. There were no problems with sex-form recognition. In the single sample examined the sex ratio was 1M:1F (Table 2).

Zygochloa paradoxa (R. Br.) S. T. Blake

Shrub-like, wiry, and rhizomatous, this is a tall species of inland sand hills. In western New South Wales in December 1987 it was still at anthesis even though seeds were present in some female florets. The male floret opens widely, and versatile, 3 mm long, maculate orange, polliniferous anthers are exserted on filaments about 5 mm long. In female florets stigmas are about 5 mm long and are exserted apically from the floret; the small (0.5 mm) sterile, white anthers emerge at the floret apex. In these characters of anthesis *Zygochloa* behaves like *Spinifex* as described by Connor (1984). In *Z. paradoxa* there is a slight excess of females reflected in their overall frequency of 0.57. In total there is a fit to 1:1 (Table 2), and the significant heterogeneity ($X^2_4 = 10.36$) is substantially contributed by the sample listed as Lake Menindee (b). No ecological differentiation for sex-form within sites was evident.

Table 1. Sex-form frequencies and allied data for *Distichlis distichophylla.*

		No. plants		Transect length m	Mean spikelets/ inflorescence		Mean florets/ spikelet		Herbarium collections
		M	F		M	F	M	F	
VICTORIA 1. Betka River, Malacoota 37°36'S 149°45'E	(a)	0	21	30	-	5.0	-	7.4	S.J. 5505, 5506
	(b)	20	2	30	3.9	-	7.8	-	
2. French Narrows 37°48'S 148°35'E	(a)	0	19	10	-	3.9	-	5.8	S.J. 5507, 5508
	(b)	0	19	12	-	3.6	-	8.4	
3. Lake Tyers Boat Ramp No.2 37°50'S 148°06'E		3*	3*	Colonies of each sex up to 50 m	3.7	4.6	9.2	6.6	S.J. 5509, 5510
4. Lake Tyers Fishermans Landing 37°50'S 148°05'E		0	1*	Colony c. 75 m	-	3.8	-	7.8	S.J. 5511, 5512
5. Lakes Entrance 37°52'S 148°00'E		1*	0	Small colony < 10 m	3.3	-	7.6	-	S.J. 5513
6. Metung Shaving Point Reserve 37°55'S 147°50'E		0	2*	Colonies c. 10 m	-	-			S.J. 5514, 5515
N.S.W 7. Lake Cargelligo 33°18'S 146°20'E		0	2*	Small colonies < 10 m	-	4.6	-	5.4	S.J. 5524
Mean					3.63±0.18	4.25±0.23	8.2±0.50	6.86±0.48	
					t = 1.747 NS		t = 1.732 NS		

Note: *Colonies not individual plants. Specimens from all populations are in National Herbariium of NSW and duplicates at CHR; numbers preceded by S.J. are S.W.L. Jacobs' collecting numbers.

Pseudochaetochloa australiensis A. Hitchc.

In this shortly rhizomatous, inland, endemic perennial, the two sex-forms are so different that they were originally described in separate genera (T. D. Macfarlane, pers. comm.). At Wyndham, Western Australia, some male plants were at anthesis in early May 1988 with the yellow anthers partly extruded apically; in the female plants some spikelets had white stigmas long-exserted apically through the dense white indumentum surrounding the involucre, while other spikelets in the same inflorescence bore mature caryopses. In the one population sampled the sex ratio did not depart from 1M:1F (Table 2).

Discussion

Sex ratios are now known for all dioecious Australian grasses even though some estimates are preliminary. In general they fit a 1M:1F ratio, but the data should not be extended beyond their limits; those for *D. distichophylla* are extensive enough to be reliable, and those for *Z. paradoxa* will reflect the composition of populations in inland New South Wales, but the sex ratio based on a single sample of *Pseudochaetochloa* must remain only a preliminary indication.

The sex ratio for *Spinifex longifolius* in Western Australia was 1M:1F, which is concordant with ratios found elsewhere on Australian coasts for *Spinifex* spp. Kirby (1988) reported an overall fit to 1M:1F for *S. sericeus* in South Australia, and for *S. hirsutus* in Western Australia, but there were some '*S. longifolius*-like' colonies mixed with *S. hirsutus* at three of his sites. In Queensland, McDonald (1983) found 1:1 in *S. sericeus*, and Maze & Whalley (1990a) reported 1M:1F for one beach in New South Wales, but an excess of males on others.

There is general agreement, too, between the sex ratios found in Australia and those in the New World grasses *Buchloe dactyloides* (Schaffner 1920, Quinn & Engel 1986, Wu et al. 1984), *Hesperochloa (Festuca) kingii* (Fox and Harrison 1981), and *Distichlis spicata* (Freeman et al. 1976). *Distichlis distichophylla* is the exception.

There was no evidence of ecological differentiation between sex-forms as reported in *Distichlis spicata* by Freeman et al. (1976), or of a shift in sex ratio with a change in ecological conditions as detected in *Hesperochloa kingii* (Fox & Harrison 1981); ecological conditions were probably too uniform at the sites examined.

The predominance of females in *D. distichophylla* must result from some factor other than the rhizomatous habit. It seems logical to assume that the local distribution reflects vegetative reproduction by fragmentation and water dispersal. This species may have been distributed vegetatively on a much larger scale than our localised samples show, because specimens held in NSW, representing its whole geographic range, are mostly female. There may be, in fact, a series of very large clones. This distribution seems unrelated to female preponderance as discussed by Lloyd (1974).

We have no data of the kind Charnov (1982) would find essential to test sex ratio theory, for example, form of sex ratio control, investment of resources, differential mortality by sex. We do, as Charnov said '...refer to adult sex ratios and question the extent of deviation from equality'; we can do little else. But for *Spinifex sericeus* some results of McDonald (1983) in Queensland and in New South Wales of Maze & Whalley (1990b) are relevant to Charnov's points. In New South Wales among plants raised from seeds (some transplanted into a dune) there were 15M and 15F; in the plants that grew from seeds sown into dunes on South Stradbroke Island, Queensland, the frequency of female inflorescences was 0.41, a little less than the frequency in natural populations.

Reproductive effort in *S. sericeus* (Maze & Whalley 1990b) is also consistent with what Lloyd & Webb (1977) consider to be generally characteristic of dioecious species in: (i) male colonies producing significantly more inflorescences than female colonies; (ii) a preponderance of male inflorescences at the beginning of the flowering season; and

Table 2. Sex-form frequencies in three grasses.

	No. plants		Frequency of females	1:1 X^2	Transect length m	Herbarium collection
	M	F				
Zygochloa paradoxa						
New South Wales Lake Menindee						
(a)	12	12	0.50	0	100	S.J. 5517, 5518, 5519 5520, 5521
(b)	11	28	0.72	7.410	100	
(c)	6	12	0.67	2.0	100	
(d)	10	18	0.64	2.286	100	
Kinchega	27	18	0.40	1.8	250	S.J. 5522, 5523
32°20'S 142°25'E Total	66	88	0.57	3.143		
Spinifex longifolius						
Western Australia Cable Beach 17°56'S 122°12'E	19	20	0.51	0.025	120	S.J. 5833, 5834, 5835
Pseudochaetochloa australiensis						
Western Australia Wyndham; Five Rivers Lookout 15°22'S 128°12'E	31	35	0.53	0.242	50 m x 10 m	S.J. 5547, 5548

Note: Specimens from all populations are in NSW and duplicates at CHR; numbers preceded by S.J. are S.W.L. Jacobs' collecting numbers.

(iii) male inflorescences producing more florets than female inflorescences. Resource investment in maleness ensures a relatively high proportion of male:female gametes early in the season, but this alone does not allow of any estimate of the opportunities for fitness gain.

In *Distichlis* there was no significant difference in the number of florets per spikelet and number of spikelets per inflorescence, and thus no suggestion of initial resource investment at different levels. Because the two sex-forms rarely co-occur and because of their habit, it may be difficult to assess quantities such as the relative number of inflorescences per plant, or relative differences in colony sizes.

Kaplan (1972) and Gregorius (1983) proposed that wind-pollinated, dioecious species maximise the average number of pollinated ovules per plant — optimal pollination efficiency — when females are in excess of males. So far, female frequency is not known to exceed 0.5 in natural populations of dioecious grasses. Either, optimal pollination efficiency is not attained, or their models are inappropriate.

These initial results are insufficient to generate new insight into sex ratio interpretation or of the significance of wind-pollination on fitness, but support the 1M:1F sex ratio, *Distichlis distichophylla* excepted. Sex-form frequency and data on differential reproductive effort measured in Australian dioecious grasses, as begun by Maze & Whalley (op.cit.), will be information of the kind which could advance knowledge of the sex ratio in the grasses, and advance its theoretical base.

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Regeneration of complex notophyll vine forest (humid subtropical rainforest) in eastern Australia – a review

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Abstract

Summerbell, Gillian (Hornsby Physiotherapy Centre, P.O. Box 1519, Hornsby, NSW, Australia 2077) 1991. Regeneration of complex notophyll vine forest (humid subtropical rainforest) in eastern Australia. – a review Cunninghamia *2(3): 391–410.* Complex notophyll vine forest (CNVF) has been perceived to be fragile and vulnerable to physical site changes and disturbances. High species richness, evenness of distribution and mixing of species provide diverse plant/animal interactions, balanced herbivore activity and a relatively predictable and constant environment. Regeneration of CNVF occurs in small canopy gaps. Environmental heterogeneity and partitioning of resources allows establishment of mature-phase species. Regeneration management aims at community stability, richness and diversity through manipulating successional pathways and re-establishing small canopy gaps. Each area must be assessed before regeneration techniques are implemented. CNVF areas in eastern Australia require active management for immediate and long-term survival. Few are large enough to be self-maintaining with a full complement of species. Each site should be managed in a regional context, to provide resources for mobile species and to conserve rare, ancient and endangered species. Any logging needs to allow for sustained species richness, diversity and highly interwoven plant/animal interactions. Selective logging based on regrowth of the overstorey or recovery of basal areas to levels similar to unlogged forests, completely ignores the composition of the forest and requirements for the community to reach full maturity. Public education, financial incentives, further research, funding aligned with enacted legislation are all necessary for effective management and conservation.

Introduction

Some 80,000 square kilometres of rainforest were present in Australia before European settlement (Webb & Tracey 1981). Today about one quarter remains.

These rainforests have great biological significance. In Queensland for example thirteen of the nineteen families of primitive angiosperms which evolved on the Gondwana continent some 120 million years ago, are present today (Vandenbeld 1988). The concentration of primitive families in the Australasian region is the greatest in the world (Webb & Tracey 1981). Two-thirds of the plant and animal species found in our rainforests are endemic to Australia (Bell 1981).

Increasing areas of rainforest have been afforded protection under World Heritage status. However, rainforests still face significant natural and man-made threats. Natural ones include fire, disease, landslides and cyclones. Human-induced threats result from tourism, recreational vehicles, introduction of exotic species, clearing for agriculture and commercial resource use (southern Queensland, Victoria and Tasmania). Active management is constrained by lack of financial resources and limited knowledge of rainforest ecology.

Complex notophyll vine forest in Australia

There are four main types of rainforest: tropical, subtropical, warm temperate and cool temperate (Webb & Tracey 1981).

Complex notophyll vine forest (CNVF), the richest form and most complex type of subtropical rainforest (Webb & Tracey 1981), is classified as subtropical vine forest, raingreen and quasi-evergreen in regions of high and seasonal summer rainfall and eutrophic soil status (Webb 1968b 1978, and Hitchcock 1976). It occurs in patches from Mossman in north Queensland to the Illawarra region in NSW, with the major part in the southern Queensland – northern NSW region. The distribution is determined by climate, topography, microclimate, soil, fire and competition. Rainfall is above 1300 mm, and soils tend to be well drained and basalt enriched (Floyd 1989). CNVF may be species rich. A hectare can contain more than 100 different trees, 60 species of vines, 70 ferns and a host of other plant forms (Churchett 1982). Floristic composition may depend not only on the physical environmental factors, but also on the distribution of relict and narrowly endemic species (Barlow & Hyland 1988).

Review of regeneration processes

Disturbance

The forest canopy is a mosaic of gaps, patches of juvenile trees in former gaps and mature forest (Whitmore 1986). The effect of different types of disturbance on rainforest will depend on the disturbance regime within which it has evolved. Disturbance which is unusual to a particular forest type will have a far greater impact than that which falls within the usual disturbance regime (Hopkins 1981).

Large-scale disturbance
This may be due to natural or man-made effects; cyclones, landslips, volcanic activity, tectonic plate movement, flooding, wildfires and logging, especially clear-felling regimes. The size of the disturbance can be from several hectares to several hundred hectares or up to many square kilometres (Webb 1977).

Medium-scale disturbance
This type of disturbance covers an area from 5 square metres to approximately 10 hectares (Webb 1977). Logging, roadways through rainforest, windthrows, local eddies and downdraughts associated with cyclones, local landslips and small fires may cause this scale of disturbance.

Small-scale disturbance or small gaps
This is usually the result of falling branches of a single tree or the death of a single tree.

Regeneration and succession

Succession is the process through which regeneration is achieved. Succession expresses the differences in colonising ability, growth and survival of organisms adapted to a particular set of conditions on an environmental gradient (Smith 1980). The replacement of one of several species or groups of species by others results from interspecific competition and the interaction of herbivores, predators and disease.

The nature of succession in a given area will depend on seed availability, conditions for germination and liberation of suppressed saplings in relation to fortuitous formation of canopy gaps, changes in microclimate and predation (Webb & Tracey 1981). Hopkins et al. (1977) divided the species of humid subtropical rainforest into four major groups, describing their survival strategies and their role in the successional process.

Group A, pioneer species
Short-lived, shade tolerant perennials that grow up to 8 metres high. They begin the regeneration process in areas of medium to large disturbance. Examples are *Rubus rosifolius* and the naturalised *Solanum mauritianum.*

Group B or early secondary species
With environmental modification these predominate and form a closed canopy. They are fast growing perennial trees (10–25 metres high) living for 15–50 years. Examples are *Euodia micrococca* and *Alphitonia excelsa.*

Group C, late secondary and Group D, mature phase species
With a canopy present these are more favoured by the altered conditions. Examples of Group C species are *Brachychiton acerifolium* and *Diploglottis,* while examples of D Group species are *Sloanea woollsii* and *Agyrodendron trifoliolatum.* By 40–50 years of regrowth, almost all the vascular species of the adjacent primary forest are represented in the under-storey. It may take another 40–50 years before the mature or Group D species have reached the fruiting stage. Secondary forests are unlikely to become reproductively independent of the adjacent primary forests until they are approximately 100 years old. This four-stage pathway of regeneration is called the 'facilitation' model (see Figure 1).

The 'tolerance' model allows for any species present before disturbance to be able to colonise the area after the disturbance. This model is commonly used to describe succession in small gaps. Opportunistic species often exploit the changed environment first, but not in every case in this model. They do not provide for more advantageous conditions for later species. Later species will only grow if they can tolerate lesser levels of resources. As in the facilitation model, the successional end point is reached when the most shade tolerant species occupy and retain the site (Smith 1980).

Delayed or arrested succession is described by the 'inhibition' model. Here, early colonists prevent the invasion of subsequent colonists or suppress growth of already existing species. This is often the case when trees and shrubs have few seeds or propagules in the soil (Hopkins et al. 1977). Succession may proceed at a later date if the dominant pioneer species is destroyed or damaged by herbivores, fires, pathogens or herbicides.

Outcomes of the successional process

Restoration of the original community

Following disturbance, secondary succession eventually restores the original community. Webb & Tracey (1981) emphasise that the disturbance must not be too extensive or too frequently repeated, and disturbed areas should be able to maintain patchiness in space and variety of serial stages in time to allow for the total display of all species available. Adequate seed sources of the original community must remain available, either stored in the soil or dispersed from adjacent living plants.

Deflected community

This occurs where partial intermittent destruction is accompanied by environmental changes persistently unfavourable for the return of the original community (Webb & Tracey 1981). Reasons for the inability of the community to regain its previous composition are discussed in the next section on breakdowns in the successional process.

Hybrid community

In hybrid communities destruction is more complete and sustained, so that some environmental changes become permanently unfavourable and seed sources become more limited. The disturbed area is colonised by pioneer species. Gradually with slow changes in local climatic and soil conditions, the original community becomes fragmentary and relict (Webb & Tracey 1981).

New community

Complete destruction of the original community and its seed sources takes place and there are many changes in the physical environment. The site is colonised by a new community depending on the proximity of seed sources of other community types and few of the original species are able to adapt and survive in competition with them.

The process of succession stops (unless delayed or arrested) when the climax stage is reached. This is the point where the community is stable and self-replicating and barring disturbances will persist indefinitely (Smith 1980). Community restoration can take up to 800 years after a widespread disturbance (Hopkins et al. 1977).

Breakdowns in the successional process

Deflected or arrested succession can result from a variety of factors (Hopkins 1981). Physical site factors such as soil compaction, soil porosity, nutritional status of soils, water table levels, can be changed by a disturbance. The pathway of succession may not proceed along facilitation or tolerance lines due to altered conditions.

Biological site factors can modify the secondary successional process in a number of ways:

(a) Lack of later phase species in the seed bank can arrest the process. A good example is the 'Big Scrub' in northern NSW, formerly a vast area of lowland subtropical rainforest extensively cleared for agriculture in the early 1900s. The forest regeneration on many of the abandoned areas now appears to be arrested at an early secondary stage (Hopkins 1981). A disturbance can expose the soil seed bank to high surface temperatures. Experiments by Hopkins & Graham (1984) on heated seeds, showed that at 60°C (a temperature reached in the summer months after about one hour's direct exposure to sunlight), half the seeds were destroyed. At 100°C, all were destroyed.

(b) Succession can be deflected or arrested if an alien species such as *Lantana camara* prevents the establishment of late phase species (see Figure 2).

(c) Geographical barriers can arrest the successional process. Many CNVF species survive in isolated pockets and largely depend on local seed availability. A major disturbance to one of these isolates is likely to arrest succession if viable seed is not available in the region (Hopkins 1981).

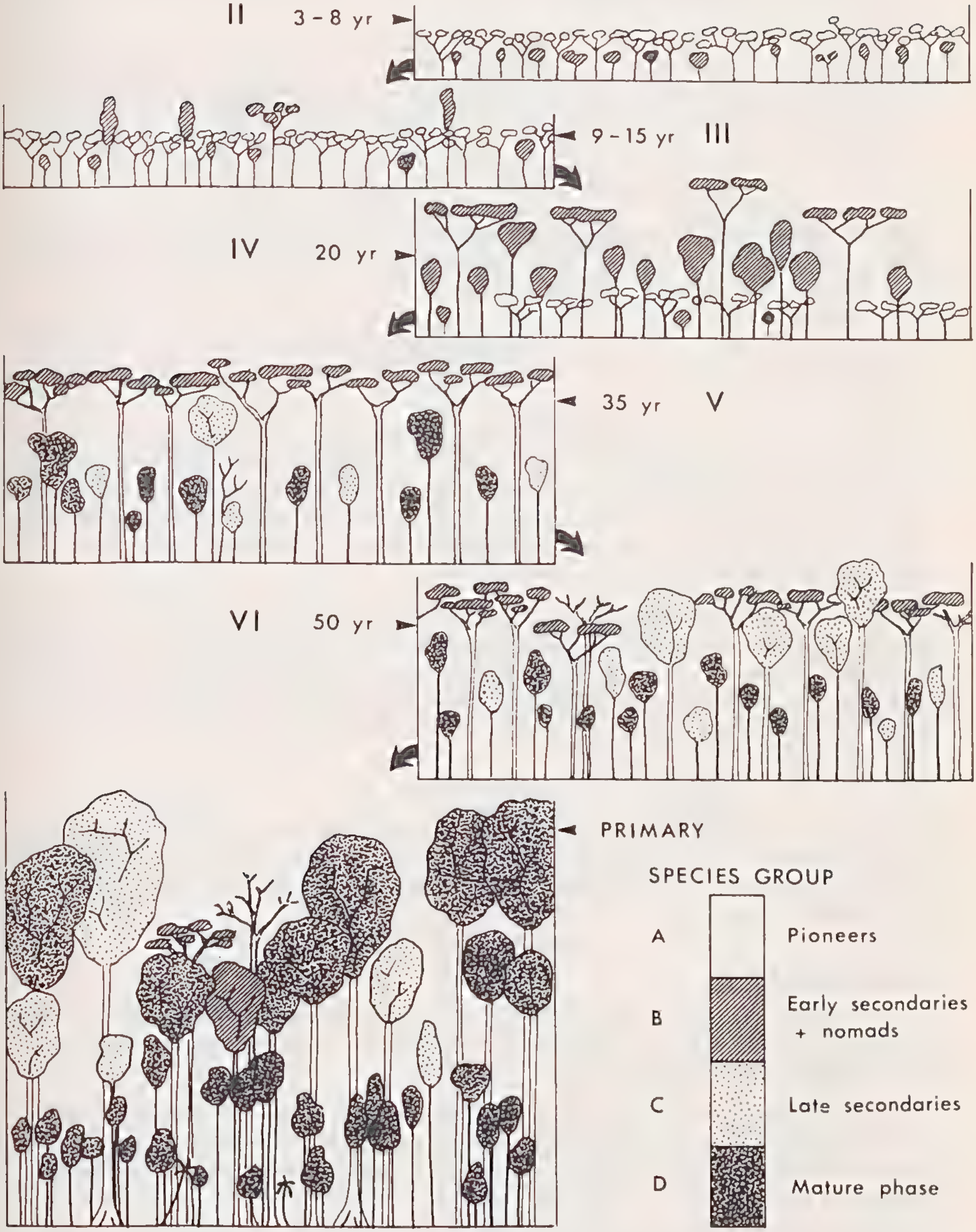

Figure 1. Schematic representation of reconstructive secondary succession in CNVF (from Hopkins 1981) (Equivalent to the Facilitation Model).

(d) Many human activities maintain the continuing occupation of sites by alien or early secondary species. Permanent openings of the forest canopy for roads, tracks and clearings allow these opportunists to occupy higher light areas. Their growth and production of profuse long-lived seeds enable them to quickly spread into other edge areas (Hopkins et al. 1977).

(e) Frequent disturbances in a community can permanently alter the species' composition diversity and hence stability of that system. Cyclone scrubs in the tropical lowland rainforests of northern Queensland are the result of frequent cyclones preventing the re-establishment of mature rainforest (Webb 1958).

Gap-phase dynamics — the gap environment

Gap creation provides an injection of new life into the rainforest community. The characteristics of the mature (D-type) rainforest species appear to have developed from gap creation. Stocker (1983) has developed a gap regeneration theory which states that in most tropical forests the component species must have evolved in relatively small gaps created by canopy disturbance. Large gaps would have been relatively rare or so infrequent that they would have little or no evolutionary significance.

Gap-phase dynamics affect many different forest processes. These include: forest structure, spatial pattern and life history features of germination, growth, time of flowering, seed dispersers and predators, herbivores, pollinators and pathogens (Bazzaz 1986.) Levels of light in the gap area have a major role in partitioning gap resources. Each species is able to achieve optimal growth in different parts of the gap or gaps of different size (Stocker 1988).

According to the size of the gap, various gap filling mechanisms contribute in gap creation. In *very small* gaps there is sapling growth and increased growth of branches of adjacent trees. In *small* gaps advanced regeneration of suppressed medium seedlings, and resprouting. In *large* gaps there is regeneration from seed bank present in the soil. Most seeds are located in the subsoil layers.

Reproduction

Four processes interact to generate the seed 'shadow' that finally produces a seedling 'shadow', namely, seed production, predation, dispersal and dormancy (Janzen & Vazquez-Yanes 1986). There is great variation in these mechanisms from pioneer to mature phase species.

Seed production

Seed production by A and B-type species occurs regularly. Large numbers of well dispersed seeds have long viability and comprise the majority of seeds in the seed bank just below the soil surface.

C or late secondary species fruit most years with seed viability mostly limited to several months, although some species can survive up to two years (Hopkins & Graham 1984). Mature phase or D-type species are characterised by infrequent gregarious flowerings which produce massive quantities of fruit (Hopkins 1975). Seeds are of a short life span, surviving from several weeks to several months. The time interval between these large fruitings is usually greater than three years. In the intervening periods, many individuals sporadically produce smaller quantities of fruit. Such gregarious flowering and fruiting appears to be general amongst rainforest tree species (Wood 1956, Ashton 1969, Medway 1972, in Hopkins 1975). During periods of gregarious fruiting, seed predation can be high.

The soil seed bank, according to Janzen & Vazquez-Yanes (1986), contains representatives of only a tiny fraction of the species of trees in tropical and subtropical forests. The seeds are in haphazard proportions having little to do with any forest structure. Hence dispersal agents are essential links in the establishment of seed shadows.

Seed dispersal

Various agents act as seed dispersers. These include wind, water, gravity, birds, bats and other small mammals. Seed dispersal is an essential process in maintaining forest diversity and regenerating disturbed areas to the original forest structure. Seed dispersal also provides new inputs of genetic material into isolated remnant areas.

The main dispersal agents in subtropical areas are wind, birds and gravity (sometimes assisted by mammals). Water and bats have lesser roles but in particular areas, can be important contributors (Hopkins 1975).

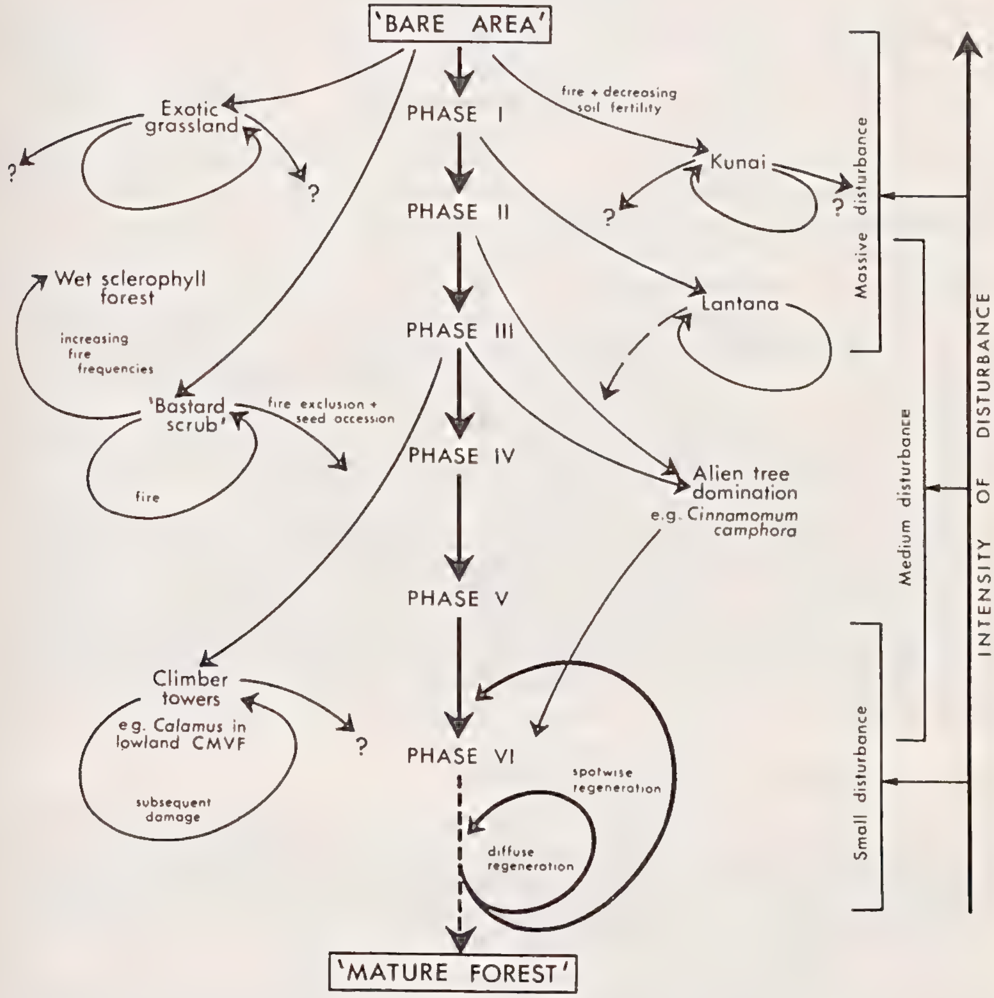

Figure 2. Schematic representation of secondary succession pathway and natural vegetation in rainforest showing some of the variations that can occur in relation to intensity of disturbance (from Hopkins 1981).

Wind-dispersed species are A and B-type species, taller canopy (D-type) species, vines, epiphytes, orchids and ferns. These species have a distinct advantage in medium-large gaps where animal dispersal is diminished.

Birds are attracted to certain colours of fruit. Blue-black and black-red are favoured over red (Floyd 1976). Fruit-eating birds can be divided into opportunists and specialists. Fruits devoured by opportunists are usually small (5–10 mm), many-seeded, often showy and usually juicy. Large fruits attract specialists, and contain few or single seeds. These fruits typify pioneer and climax species respectively (Whitmore 1983). This situation has implications for isolated communities where specialist migratory birds are needed for seed dispersal. Seed dispersal by animals often involves enrichment of the seed by the animal to increase its ability to germinate and also leaching of germination inhibitors.

Seed predation

Seed predation shows no particular pattern. It can vary markedly from year to year, tree to tree and habitat to habitat. Different species have different susceptibilities to different seed predators (Janzen & Vazquez-Yanes 1986). Mammals and insects are the main seed predators in humid subtropical rainforest. Evidence does show that animal predation directly affects the survival and pattern of distribution of seedlings of particular rainforest species (Janzen 1972, Wilson & Janzen 1972, in Hopkins 1975). Hopkins (1975) feels there is little doubt that damage by plant predators and parasites, whether animal, fungi, bacterial or viral, can be a controlling factor affecting the establishment and survival of plants.

Seed dormancy and germination

Seeds of subtropical plants have variable dormancy periods. Germination may occur quickly when the seed is moistened or delayed until the hard seed coat is broken down. Bird ingestion and excretion can accelerate the germination process by several months, as in the case of *Cryptocarya glaucescens* (three months if ingested; six months if not). Many of the short-lived fast growing early secondary species have hard seed coats, which remain buried in the soil for many years (Floyd 1976).

In subtropical rainforests with a definite dry season, seeds may remain dormant if the fruits mature in the dry season. Once the rainy season begins, germination commences (Janzen & Vazquez-Yanes 1986). Stocker (1988) examined the role between fruiting, seed predation and germination in shade-tolerant species. He felt that with the favourable establishment environment for shade-tolerant species and the effects of predation on large seeds of this group, immediate rather than delayed germination has evolved.

Role of pollinators in flowering and fruiting

Plants with a large flower crop tend to be pollinated by large unspecialised pollinators, for example, birds, bats and moths, and tend to flower in synchrony over a short period (Pomeroy & Service 1986). Bawa & Krugman (1986) have suggested that pollinators probably switch from one species to another as the floral resources of one species decline and that of the other increase.

An alternative strategy is to produce a few flowers at a time over a long period, for pollination by specific animal species. These pollinators tend to be birds, butterflies, large moths or large bees (Pomeroy & Service 1986).

Loss of food resources for pollinators or removal of that pollinator from the community may influence pollinator guilds and consequently plant guilds that depend upon these pollinators (Bawa & Krugman 1986). Management strategies require an understanding of pollination modes and the extent to which various plant species are dependent upon particular pollinators. Unfortunately, very little is known about pollination biology in tropical or subtropical forests.

Coppicing

At a subtropical rainforest site in Queensland, 74 of the 82 regenerating species coppiced after felling and burning (Stocker 1981, in Whitmore 1983). The growth of these coppiced species was slower than for trees regenerating from seed. Webb et al. (1972) observed that plants with coppice growth were taller than plants regenerating from seeds at Mount Glorious in southern Queensland and concluded that coppicing conferred a considerable competitive advantage to a plant.

In Lamington National Park in an area regenerating after storm damage, 35 of the 44 tree species present were suckering or sprouting (Olsen & Lamb 1988). Turner (1976) noticed coppicing in some species on steep slopes at Barrington Tops, NSW. He felt the coppicing pattern suggested an element of genetic control, that would enable the better adaptive traits of tree species in the particular environment to be retained.

Rainforest fauna

Birds

Some 90 bird species regularly breed within the rainforests of NSW but only 38 depend on rainforest for the majority of their food or breeding requirements (Morris (1976). Birds may depend on patches of rainforest scattered over thousands of kilometres. Crome (1975) found seven species of fruit pigeons in northern Queensland were nomadic and migratory, with their movements related to tree species and the quantities of fruit available. Competition between species was minimised by this utilisation of different food plants.

Kikkawa (1968) studied the ecological association of bird species in northern NSW and northern Queensland. In northern NSW, the subtropical rainforest areas supported fewer bird species than the dry habitats and he concluded that the avian fauna was impoverished and did not form a unique association with rainforest. By comparison, the rainforests of northern Queensland included a high proportion of 'regular species', where more than half the species utilised this habitat exclusively. Kikkawa (1968) feels that successful colonisation of subtropical rainforest in northern NSW must have been largely limited to those species that had developed or retained adaptions favourable to wet formations in general. Various authors (Gentilli 1949; Keast 1961 and Brereton & Kikkawa 1963, in Kikkawa 1968) have suggested that the poor faunal diversity in rainforest may be explained in terms of past climate and the patterns of speciation and colonisation on the Australian continent.

Mammals

There are no mammals (excluding bats) which exclusively inhabit the CNVF areas of south-eastern Australia. The 41 species of mammals which have been recorded in tropical and sub-tropical areas are only forest generalists and ecotone species (Winter 1988). Absence of specialists is felt to be due to refugia shrinking some 25,000 to 15,000 years ago below the critical size required to maintain a specialist community Bats contribute about one quarter of the total number of mammal species using northern NSW rainforests. Thirty-two species have been recorded, some of which exclusively depend on the rainforest environment (Adam 1987).

Invertebrates

Invertebrates act as seed dispersers, seed predators and pollination vectors. Compared with the vertebrates, many of the rainforest invertebrates are highly specialised in their habitat requirements, being restricted to particular host plant species and in many cases having specific hosts for different stages in their life history (Adam 1987).

Invertebrates as herbivores consume between 10 and 20 per cent of plant material. Young leaves and seedlings appear especially vulnerable (Bazzaz 1986). Injured leaves have been shown to lose more nutrients from leaching than uninjured leaves (Turkey 1970, in Golley 1983). These injured leaves decompose earlier, providing nutrients for special plant requirements such as fruit formation (Golley 1983). Insects, by their defecation systems and short life cycles, also provide a quick release of nutrients for plant usage. Insects can have detrimental effects. Overgrazing can upset the successional process by allowing early successional species to persist under high light levels. Insects cause mortality by providing entry for pathogens and changes in tree structure can arise from loss of plant support tissue (Bazzaz 1986).

Herbivory can vary from site to site due to subtle changes in environmental factors or plant composition. Seasonal variation can be marked as a result of seasonal effects on an invertebrates life cycle or seasonal changes in levels of food supplies (Lowman 1982). Some insects require resources from both mature forests and successional habitats. For example, some aroids and orchids are pollinated by specialist species of euglossine bees, but the bees often require early successional plant species for larval resources (Frankel & Soule 1981). Many tropical pollinators have low population densities, which are susceptible to area effects including the stochastic, demographic and genetic events which are characteristic of small populations (Frankel & Soule 1981). Any reduction in area is likely to result in the extinction of some pollinators and loss of essential catalysts for fertilisation of certain plant species.

Studies on regeneration of humid subtropical rainforest

Studies of the recovery of humid sub-tropical rainforest (CNVF) in Australia have largely been based in the Border Ranges and Lamington national parks area. As this is the largest remaining area of CNVF, one would expect recovery ability to be higher than that of small isolated remnants. Observations at O'Reillys in Lamington National Park on an area cleared and burnt have shown CNVF can recover from a severe man-made disturbance, under certain conditions. Hopkins et al. (1977) describe these conditions as the time since the original clearing, the completeness of the clearing, the effectiveness of the burn and the proximity and type of adjacent forest. Succession started with A-type species and followed along the lines of the facilitation pathway. The developing forest in 1977 was becoming increasingly similar to the adjacent primary forest.

Olsen & Lamb (1988) monitored the recovery of an area of forest near O'Reillys after a heavy storm in September 1983 destroyed the forest canopy, creating a large gap. Some isolated trees remained. A year later, early secondary species were growing along with vines, exotic weed species and shrubs. Two years later, primary forest species were regenerating. Thirty-five of 44 species originally present were growing by sprouting. Possible explanations suggested for the quick regrowth of primary forest species after this disturbance were that:

(a) Propagules of some of the primary forest species were shed from residential trees within the gap, although little seed would have been possible due to substantial crown damage.

(b) Residual trees may have acted as important focal points for fruit-eating birds, accelerating the arrival of new tree seed.

(c) In microclimatic terms a large gap may really be the equivalent of a 'small gap' in a tropical rainforest because of the lower solar angle. In a gap with residual trees, the overall effect of these factors may discriminate against some secondary species. Regeneration in this situation has proceeded along the tolerance pathway.

Predictions by modelling of recovery times for CNVF with different logging regimes have been made in the Wiangaree State Forest (now part of the Border Ranges National Park), an area of 14,000 hectares (Shugart et al. 1980; Horne & Gwalter 1982). Horne & Gwalter (1982) estimated the time of recovery of the overstorey after full utilisation logging — i.e. 70–80 per cent removal of the basal area of overstorey — to be longer than 200 years. With more selective logging, namely 33 per cent removal of the basal area overstorey and 50 per cent canopy retention method, recovery time would be approximately 30–60 years. Presumably, regeneration would take the pathway of the facilitation model with full utilisation logging and the tolerance pathway with selective practices.

The model of Shugart et al. (1980) was used to assess the consequences of the harvest of commercial species from CNVF both in terms of single harvest or a repeated harvest. The model predicted increases in the basal area of a number of species would peak 30–50 years following logging and indicated that CNVF should have the regenerative capacity to sustain a conservative logging program on a 30-year cutting cycle.

Predictions in both these studies have implications for the reproductive biology of primary forest species. If D-type species do not produce fruit until 40–50 years old and are not reproductively independent of adjacent primary forests until approximately 100 years old (Baur 1964, Hopkins et al. 1977), how could these forests continue to regenerate to the original forest composition if they are logged on a 30-year cycle? Over several cycles there would have to be a shift in species composition to the early and late secondary species, altering the stability of the forest, animal-plant interactions and threatening the survival of some species.

Modelling predictions by Horne & Gwalter (1982) tend to favour increases of group C species in their occupation of the canopy over group D species. *Doryphora sassafras* increases from 0–10 per cent and *Cinnamomum oliveri* from 2–10 per cent of the canopy, while *Endiandra sieberi* decreases from 31–18 per cent. The authors have stated that logging may cause some alteration in the relative frequencies of the major overstorey species due to their different growth rates. Hence, after several cutting cycles, few adult group D species would be present.

Managements of isolates

Problems of remnants

Remnants or isolates can be classified into two broad types, artificial and natural, depending on whether the isolation was produced quickly by humans or developed naturally in response to longer term changes in climatic and geomorphological processes that usually involve fire. One would expect the abilities of remnants to adapt and survive the various changes brought about by development would be different. The survival of natural remnants tends to suggest that they have adapted to their isolation (Webb et al. 1985).

Remnants face greater threats to the maintenance of community stability than larger reserves. Remnants have a larger ratio of boundary to core area compared with larger reserves. Boundary areas serve as entry points for more competitive exotic species which can initiate interference patterns and inhibit successional pathways. A remnant's microclimate is influenced by the surrounding vegetation. It is likely to be different to a larger reserve with lower humidity levels and higher temperatures.

Current knowledge of the boundary dynamics between rainforest and other vegetation types is extremely limited. A large number of remnants are adjacent to eucalypt forests. Many of the early successional gap opportunitists have characteristics which can successfully colonise these margins. Fire is one disturbance where these colonisers must have special adaption as it is an uncommon event in rainforests. Regular fires in these marginal areas cause species impoverishment and gradual contraction of the isolate (Webb et al. 1985).

Remnants generally need an incoming supply of seeds for genetic variety, species maintenance and continuing community viability. The size of the remnant, the distance of the remnant from the nearest seed sources and the boundaries across which seed dispersers must travel will determine seed dispersal processes. Seed dispersal has an important role in gap regeneration processes. Gap regeneration allows a community to maintain its species richness and diversity. Any interference to these processes by exotic species and human activities, namely a decrease in isolate size or increase in gap size and gap turnover rates, will favour the regeneration of early successional species over mature phase species (Webb et al. 1985). A loss of certain mature phase species will set in motion loss of animal species, increased herbivory and susceptibility to disease. Raven (1976, in Frankel & Soule 1981) has emphasised the high level of specialisation and interdependence of tropical species and predicts that the loss of a plant species can trigger the demise of between 10 and 30 animal species. Frankel & Soule (1981) labelled species which have widespread roles with plant/animal interactions as 'key' species. Table 1 shows the cause and effect relationships following the extinction of several types of key species. Gilbert (1980), (in Frankel & Soule 1981) has described 'mobile links' and 'keystone mutualists' in the synthesis of tropical plant-insect relationships. A 'mobile link' is an animal that is a significant factor in the persistence of distant plant-herbivore communities. Keystone plants are usually sources of nectar, fruit or pollen and provide critical support to mobile link species. These plants include tree genera such as *Ficus*, epiphytes, and early successional plants such as *Solanum* and *Passiflora*. Many keystone plants require early successional habitats or gaps.

For survival of animal species, the situation is quite intricate. Soule (1982, in Webb 1987) and other zoologists consider 500 individuals as a safe minimum level for breeding adults, but there are stipulations and complications due to genetic factors and the effects of logging. Thus, species collapse from inappropriate gap dynamics and unwanted edge effects is perhaps the greatest biological threat to the maintenance of community stability in remnant areas.

The management objectives for a CNVF area are:

1. *A stable community* by manipulation of successional processes (if necessary).

2. *Restoration of the canopy* if it is degraded or disturbed *aligned with the use of canopy gaps*. Where a medium-large disturbance has produced a large canopy opening, reduction to small canopy gaps by the establishment of early secondary species will provide the appropriate environment for the germination and growth of shade tolerant mature phase species. Canopy gaps will need assessment of understorey and soil status and possibly subsequent treatment to provide for environmental heterogeneity.

3. *Restoration of the lower canopy, forest floor and edge areas.*

4. *Identification of key species* of the particular community and additional plantings (if necessary) within their regeneration and habitat niche.

5. When a stable community has developed, *different levels of successional change* are required for resources for animal species and continuing community diversity.

(Webb et al. 1985, Stockard et al. 1985, Hynes 1983, Frankel & Soule 1981)

The processes by which these management objectives will be obtained are:

Thorough assessment of the area
- natural disturbance
- successional pathway stages
- interference
- exotic species
- rare and endangered species
- key plant and animal species
- human disturbance
- incompatible activities

Planning and implementation of management plans
- local objectives
- priorities for action
- techniques of regeneration
- management of incompatible and human activities

Monitoring and research
- assess regeneration techniques
- changes in objectives/priorities/techniques?

Coordination between government agencies and agencies involved in the regeneration process

(Godfrey et al. 1988, Hopkins et al. 1977, Hopkins & Saunders 1987)

The techniques used will be many and varied as each CNVF area is slightly different in community structure, levels of degradation, physical site characteristics and historical evolution. An explanation of techniques used is given in Table 2.

Constraints to management

Constraints to management are just as much a threat to the future of these rainforests as their small size and geographical isolation. Inscribing these areas in NSW on the World Heritage List does not ensure their continued survival without adequate management. Management needs to be bound to some form of enacted legislation to provide funding for assessment, management practices, research and monitoring. At present there is no effective endangered species and community legislation in NSW.

Constraints to management are:

Funding — Rainforest management should be intensive and ongoing. The Federal Government has allocated over $20 million for a National Rainforest Conservation program (Department of Arts, Heritage & Environment 1987), whether funding for regeneration of degraded areas has been included, is unknown to the author. Funding must also come through endangered habitat legislation, as previously mentioned.

Data on synecological and autecological aspects of humid subtropical rainforest are quite limited — This must restrict the potential effectiveness of management. The importance of increased research and monitoring cannot be overemphasised.

Table 1. Some possible cause and effect relationships following the extinction of four kinds of key species, with particular emphasis on tropical forests (Frankel & Soule 1981).

Ecological category	**Cause of local extinction**	**Effects of extinctions on diversity**	**Indirect effects**
I. Large predators	area effects increases	herbivore density increases	habitat destruction from overbrowsing, compaction, grazing, trampling and predation
	hunting	competitive excusion among prey species	extinction of ground nesters, plants
II. Large herbivores	area effects	extinction of large predators	the *Indirect effects* in row III
	hunting	loss of early successional habitats	
III. Generalized key species (e.g. bees, butterflies, bats and birds)	area effects	reproductive failure from reduced pollination and seed dispersal in low density plants lacking specialized mutualists	extinction of plants
	loss of early successional habitats		extinction of specialized herbivores extinction of specialized parasitoids and predators destabilization of coevolved food webs
IV. Certain critical plants	commercial collecting or selective cutting	starvation and emigration of generalist pollinators	*Indirect effects* in row III
	loss of early successional habitats		

Lack of public awareness of the fragility of rainforest environments — Human disturbances to small areas can be just as, if not more damaging, than a natural disturbance. Human disturbances can be of an ongoing nature which may not permit the regeneration process to reach beyond the pioneer stage. Management plans must consider all present and future human threats and incorporate appropriate actions to eradicate or minimise these destructive influences.

Few trained personnel with expertise in rainforest management — Many of the CNVF areas have only recently come under the protection of World Heritage status, hence management of these areas is in its infancy and few have had time to experience this field of reserve management.

Lack of communication — Co-ordination between multiple government agencies could retard the efficacy of management and conservation of rare and endangered species.

Discussion

The richness and complexity of CNVF is bound in the biotic elements of the community. The vegetation holds the majority of the nutrients within its living tissue, the plant species diversity provides a vast range of resources for animals and a buffer to the overexploitation by herbivores, predators and pathogens. The large variety of animals in turn acts as a catalyst in essential plant reproductive strategies to maintain species diversity.

The type of disturbance and its effects on the physical environment will determine the recovery process. Hopkins (1975) mentions that where the disturbance is artificially maintained by roads and clearings, the ability to regenerate is threatened. The physical effects of machinery may provide inappropriate establishment conditions (Webb et al. 1972). Where a massive disturbance occurs the final composition of the vegetation would also be expected to be determined by the floristic composition of the adjacent forest. This has obvious implications for remnants where the adjacent forest is unlikely to be CNVF.

Considering stability and specialised interrelationships of subtropical species, what reserve sizes will be necessary to preserve all species of CNVF? This question is difficult to answer due to lack of information on rainforest species populations and ecosystems. Ashton (1976, in Webb 1987) considered that 200 mature individuals was the minimum effective population size for rainforest trees. In 1000 hectares of forest (for the complex forests of Borneo), 60 per cent of the species should be left intact and in 2000 hectares, all but the rarest species would be likely to be conserved. Webb (1987) suggests that 'even undisturbed reserves (that is, not too drastically disturbed by people who inhabit all of the surrounding areas) may already be too small to be self-sustaining in the longer term, i.e. on time scales reckoned by centuries. Besides adverse social pressures, biological factors include loss of essential fauna for pollination and seed dispersal, a slow run-down in genetic fitness, and population sizes that are already too small to prevent species extinction.'

Hopkins (1975) feels that substantially larger areas of rainforest are needed to retain 'stability' than are necessary in more simple vegetation types. He predicts that any restriction on this 'habitat species area' could lead to gradual simplification of the community. Many reserves are too small to always contain all the necessary successional stages for the persistence of some herbivore species (Frankel & Soule 1981). The role of key species needs more identification and research. The fact that these species can have a profound role means that management should clearly be preserving and monitoring their activities.

Community education about the fragility of rainforests is needed to assist the preservation of remnants of CNVF. The misuse of Wingham Brush until fairly recently is an example of the little understanding the general public have of rainforest complexity and stability. Community service groups, local media, lectures in schools and interpretative signs on site are useful ways of providing this information.

The general public are not the only ones ignorant of conservation. Mills (1987) expresses much concern at the lack of appreciation of rainforest conservation by government. Pressure on the remnant vegetation of the Illawarra Region increases weekly, not uncommonly emanating from the activities of government departments. The development of service corridors, coal mines and their associated waste disposal dumps and urban expansion have taken their toll in recent years.

Table 2. Aims and techniques for the restoration of degraded CNVF sites (Floyd 1984, Stockard et al. 1985 & Kooyman 1988).

Forest	Causes of degradation	Techniques for restoration
Canopy	vine overgrowth	mechanical and chemical means (Glyphosphate, e.g. Roundup) – follow up treatment at periodic intervals; initial canopy vine treatments should be undertaken in the non-growing season.
	large canopy gaps from disturbance	suitable fast growing A & B Group species; or use of clump plantings – a mixture of AB & CD Group species with shrubs and palms and A & B type species in between clumps. Clump plantings provide quicker re-establishment of the rainforest environment, structure and pattern of species distribution. Use of local species where possible.
Rainforest edge	vine overgrowth; exotic species	mechanical and chemical means; treatment here is more successful after the main canopy has been treated, otherwise light conditions will allow edge species especially exotics to enter the rainforest body.
Lower canopy and forest floor	vine overgrowth; exotic species	mechanical and chemical means after the overhead canopy is intact and weed-free for 2-3 years.
Incompatible trees, e.g. *Cinnamonum camphora*	promote fire, out-compete native species	mechanical/chemical means.
Steep slopes	exotic species	where use of machinery is restricted or it is unsuitable to clear the whole site, contour line clearing is used; clump planting re-establishes a canopy and shades light demanding exotics; ongoing maintenance required.
Exposed sites	high velocity winds	windbreaks to protect seedling trees; examples include *Pittosporum undulatum* and *Acacia melanoxylon*.
Frost-prone sites	frost affecting growth of C & D Group species	nurse crop of A & B Group species such as *Macaranga tanarius* and *Commersonia bartramia*.
Grassed areas		mechanical and chemical means to remove grass; begin spraying 2 weeks prior to planting and follow up spraying for around 3-4 years; use of newspaper and bagasse mulch will markedly reduce the need to continue spraying.
Cleared lands with remnant trees	agricultural pursuits	fencing to exclude stock; single and multiple clump plantings with a great mix of species and suitable edge species; palms and shrubs can be planted in between clumps

Multiple commercial use of tropical forests may be economically desirable but, in practice, slowly simplifies the community. Logging in humid subtropical rainforests, currently only being practised in Queensland, clearly needs more monitoring and research to justify the 30 to 60-year logging cycles, advocated by Shugart et al. (1980) and Horne & Gwalter (1982). All of the studies undertaken have described a shift in species from mature phase to late secondary ones with logging in this time-frame. With the current knowledge on CNVF, harvesting every 30–60 years cannot be described as sustainable forest management.

Baur (1964) described rainforest trees as having great variations in diameter growth in individual trees of similar age and species and advocated more emphasis be placed on plantation establishment. He stated that species are known to be capable of producing mature trees in half the time or less from plantations. However monoculture plantations have not been successful to date. Webb (1968a) reported that *Grevillea robusta* (a non-gregarious tree species) 'checked' after about 10 years. Seedlings of *G. robusta* did not persist in these plantations due to intraspecific competition from the adult species. Other species have been susceptible to insect attacks, fungi, pathogens etc. Stocker has described the most useful tropical rainforest species as those possessing a high degree of shade tolerance and suggests growth at high light levels is inversely related to their shade tolerance. Hence, the scope for greatly increasing the productivity of tropical rain-forests by silvicultural modification is limited. Stocker (1983) advocates growing large gap-type species in plantation environments.

Further research is of paramount importance if future management is to intimately understand the dynamics and floristic patters of the CNVF environment and be able to predict the effects of management practices. Research must largely be based in situ rather than in the laboratory, as Webb (1968a) has illustrated. What happens in an artificial situation is quite different to normal community interactions.

The importance of protecting all areas of humid subtropical rainforest cannot be overstated. Government agencies with control of CNVF areas have to become more aware of their uniqueness, fragility and need for active management. Placing an area under a reserve or national park status without specialised management will not guarantee the stability and viability of this area in the future. Assessments need to be undertaken of each area and plans of management developed.

A system of managed reserves requires conservation agreements with private landholders. These agreements appear most successful where economic incentives are available through tax write-off and rate relief schemes. With only 3 per cent of CNVF in private lands in NSW, it would not be an expensive measure to be able to protect the remaining endangered species.

For management plans to be implemented, they need to be bound to legislation such as the Victorian Flora and Fauna Guarantee Act, 1988 to obtain appropriate funding. This Act provides a strong legislative basis for the conservation of threatened species in Victoria by listing all threatened species and communities, preparing policy statements on each species and community and then preparing management plans for all listed species. At present, there is no similar legislation in NSW, although, the National Parks and Wildlife Service is preparing a discussion paper on projected legislation (Kennedy 1989). One hopes a similar decisive act will be introduced in NSW.

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Vegetation on rocky outcrops and ranges in central and south-western New South Wales

E.H. Norris and J. Thomas

Abstract

Norris, E.H. & Thomas, J. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia 2000) 1991. Vegetation on rocky outcrops and ranges in central and south-western New South Wales.* Cunninghamia *2(3): 411–441.* The natural vegetation of rocky outcrops and ranges in the Lake Cargelligo, Griffith and Berrigan district (33°19'S 146°22'E to 35°40'S 145°49'E) is described (Central Western Slopes, South Western Slopes and South Western Plains botanical subdivisions). Nineteen sites were sampled on different geological types: sandstone, granite, slate and rhyolite. Vegetation in general is eucalypt woodland with a mixed shrubby to herbaceous understorey. Plant communities relate to geological type. A list of 338 species (283 native, 55 exotic) is provided. Isolation of the vegetation as a result of clearing for agriculture, and the disturbance of many of these sites by feral animals, grazing and quarrying are important factors to consider for future conservation and management.

Introduction

Low ranges and isolated rocky outcrops representing the boundary between outcropping Palaeozoic bedrock and the Tertiary/Quaternary alluvial plains flank the eastern edge of the South Western Plains of New South Wales. Being less accessible and having generally poorer soils, these outcrops often retain the only natural vegetation in a landscape substantially modified by agricultural use. Some are conserved as National Parks or Nature Reserves, whilst others, such as Mount Galore, are under the control of local Shire Councils. Others are subject to varying degrees of grazing and other land use.

Little information is available on the vegetation of these outcrops, especially the smaller ones (NSW National Parks & Wildlife Service, Forestry Commission of NSW and the Soil Conservation Service of NSW pers. comm.). This study examines rocky outcrops and ranges between the towns of Lake Cargelligo in the north and Corowa in the south (300 km apart), and between Ardlethan in the east and Jerilderie to the west (110 km apart) (Figure 1). These include the Cocoparra, Lachlan and McPhersons Ranges, Boat Hill and Mount Boomanoomana. Also included were the Keginni Range north of Roto, and Manfred Range south of Darnick. An initial account of the vegetation of these rocky areas and their potential conservation significance is provided.

Geology and soils

The rocky outcrops within the study area comprise Palaeozoic geosynclinal sediments within the Lachlan Geosyncline, a marine trough forming part of the Central and Southern Highland Fold Belt (Packham 1969; Butler et al. 1973)). Part of the Lachlan Geosyncline is characterized by a wide belt of Ordovician sedimentary and

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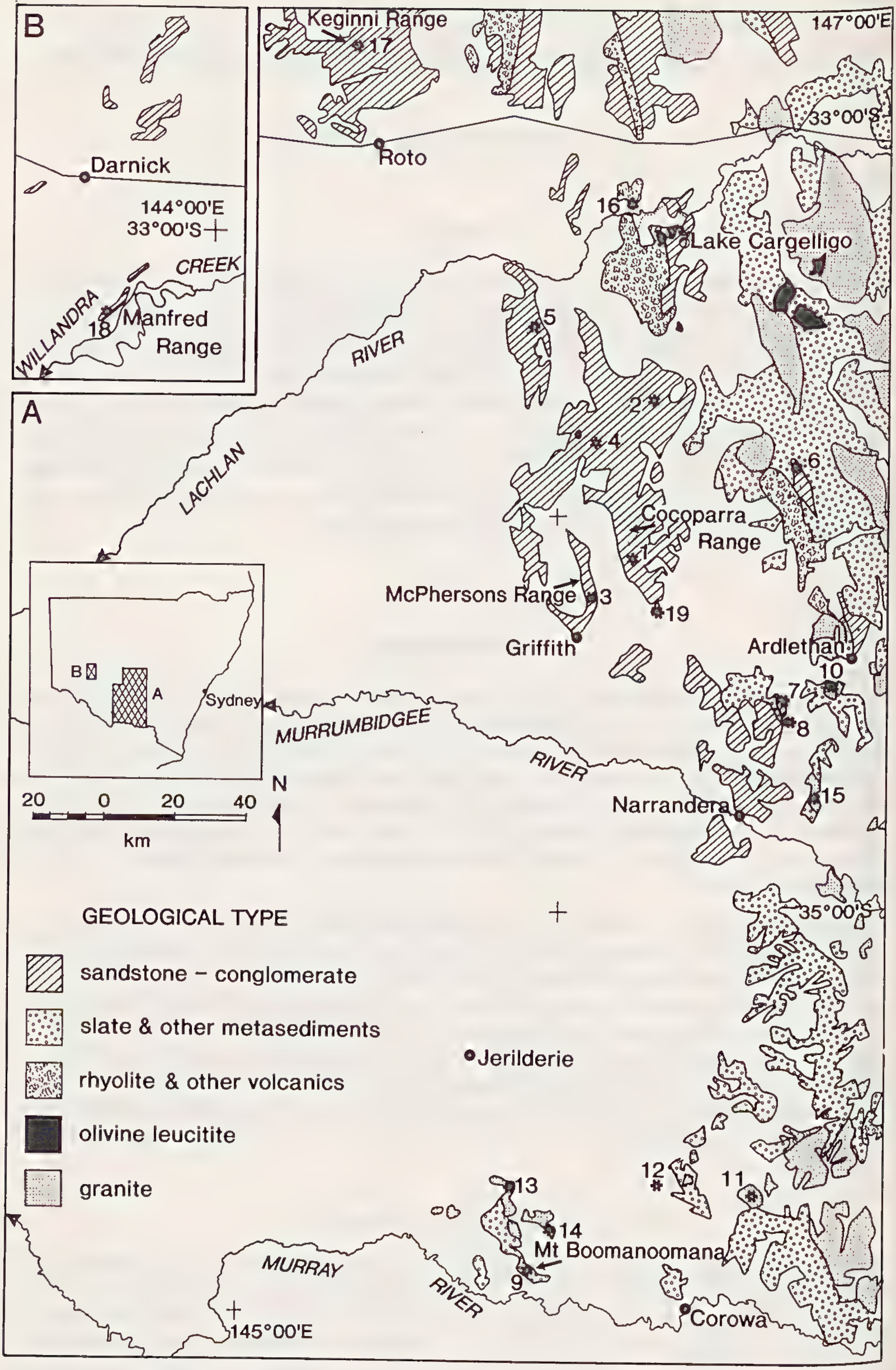

Figure 1. Map showing the study area and the main geological types (modified from Geological Survey of New South Wales (1972)). Numbers refer to sites. Major towns and rivers are also shown.

metamorphic rocks and granite masses (the Wagga Metamorphic Belt), with the western flank comprising a large area of Upper Devonian quartz sandstones of the Cocoparra Group. Some minor occurrences of possible Silurian sediments and volcanics can be found within its boundaries (Packham 1969). Hills north and west of Lake Cargelligo are formed on quartz-feldspar porphyries and rhyolites. Sandstones of the Mulga Downs Group outcrop in the northern and western section of the study area and include the Keginni and Manfred Ranges respectively (Geological Survey of New South Wales various dates 1971, 1968) (Figure 1, Table 1).

Skeletal soils or lithosols occur where rock is near the surface. These comprise shallow sands, loams and clay loams and are always stony or gravelly due to the presence of fragmented rock material showing some degree of weathering. (Stace et al 1968). Sandstone lithosols are found at sites in the Manfred, Keginni and Cocoparra Ranges, at Mount Bunganbil, Mount Wammera and sections of Jimberoo Creek State Forest.

Deeper soils derived from sandstones, mapped as massive, neutral red earths (Soil Conservation Service 1986), occur on slopes in Cocoparra National Park, the Lachlan and McPhersons Ranges and Jimberoo Creek State Forest . These soils are mainly sandy in texture, red-brown to brown in colour with a weak profile differentiation gradually increasing in clay content with depth (Stace et al 1968).

Surface weathering of granite usually produces a shallow sandy loam. Such soils can be found at sites including Berrigan, Grong Grong and parts of Mount Goombargana. Granite-derived soils at sites influenced by slope tend to have a contrasting profile with the A-horizon being a loamy sand to sandy loam 20–30 mm thick overlying a very sandy clay. Such profiles occur at several sites including Mount Goombargana, Bald Hill Tank and The Boat Hill.

Geomorphology

The landscape is characterised by depositional sand and flood plains surrounded by a margin of low relief erosional landforms rising 30 to 300 m above the adjacent plains (Palfreyman 1984). Erosion has resulted in valley incision with narrow alluvial valleys within the ranges and bands of alluvial and colluvial material around the footslopes. The long continued action of streams is evident by the depth of alluvium accumulated on the plains to the west (Butler et al 1973).

Vegetation

Prior to European settlement, the vegetation of the region was a mosaic of open-forest, mallee and *Acacia pendula* shrublands on the plains country, whilst the outcrops and ranges carried forests and woodlands. Allan Cunningham (1817) collected species from these outcrops and ranges including *Hibbertia, Goodenia, Grevillea* and *Prostanthera* from Mount Narriah and the Cocoparra Range.

Cambage (1901) recorded species between Mount Hope and Parkes, Beadle (1948) described the *Eucalyptus dealbata – E. sideroxylon* Association (using the name *E. dealbata* for what we now know as *E. dwyeri*) occurring on some of these rocky outcrops with notes on soils and erosion, and Moore (1953) described vegetation alliances of the south-eastern Riverina, listing species and discussing the relationships between vegetation and environmental factors. There are also species lists for prominent outcrops and ranges such as The Rock, Mount Galore and Cocoparra National Park and Nature Reserve (Willis 1967; Logan 1974; National Parks & Wildlife Service no date; Bladen no date; Burrows 1989). Cunningham et al (1981) include habit and habitat details for species recorded from these rocky outcrops and ranges. The Con-

Table 1. Site number, locality, map sheet and grid reference (1:250 000 topographic sheet); elevation (m) and area (ha), geology and field observations for sites recorded in this survey.

Site no.	Locality map sheet grid ref.	Elevation (m) area (ha)	Geology	Field observations
1	Mt Bingar NARRANDERA GR 424785	455 m >1000 ha	Late Devonian Cocoparra Group: pebbly sandstone with thin conglomerate bands, sandstone and lithic sandstone	sandstone; shallow brown sandy loam, c. 10cm deep; stones on surface
2	Jimberoo Ck State Forest CARGELLIGO GR 427837	c.300 m >1000 ha	Cocoparra Group: sandstone and siltstone, orthoquartzitic sandstone	sandstone; slope area - dark sandy skeletal material, well drained ridge area - brown loamy sand, shallow and stony, many boulders
3	McPhersons Range NARRANDERA GR 409778	254 m >1000 ha	as for Site 1	sandstone; soils generally thin; clayey on footslopes & small benches
4	Flagstaff Hill CARGELLIGO GR 410824	380 m >1000 ha	as for Site 1	sandstone; hard compacted reddish clay
5	Lachlan Range CARGELLIGO GR 397855	c. 340 m >1000 ha	as for Site 1	no field data
6	Mt Narriah CARGELLIGO GR 472816	486 m c. 500 ha	as for Site 2	sandstone, abundant outcrops; soils skeletal sandy in parts; more clayey in bench & saddle areas
7	Mt Bunganbil NARRANDERA GR 467743	c. 300 m c. 700 ha	Cocoparra Group: conglomerate, pebbly sandstone, sandstone & siltstone, lithic sandstone	sandstone; shallow loamy well drained soils; deeper soils on benches; summit & eastern aspect with sandy skeletal soil and large exposed bedrock areas
8	Mt Wammera NARRANDERA GR 471734	331 m 200 ha	as for Site 7	sandstone & pebbly sandstone; footslopes - damp shallow clayey sand; westerly bench - shallow sandy soils, deep in parts with higher clay content

Site No.	Locality map sheet grid ref.	Elevation (m) area (ha)	Geology	Field observations
9	Mt Booman-oomana JERILDERIE GR 390567	255 m c. 600 ha	Ordovician low grade metasediments: slates, phyllites, quartzose greywacke	metasediments; shallow sandy soils with many stone fragments on the surface in more exposed areas
10	Bald Hill Tank NARRANDERA GR 483745	284 m <100 ha	Middle Silurian Ardlethan Granite: porphyritic muscovite-biotite granite	granite; coarse sandy granitic soil, shallow in parts over exposed bedrock; seepage areas on lower slopes.
11	Mt Goombargana JERILDERIE GR 459591	403 m c. 600 ha	Jindera Granite: biotite granite	granite; coarse granitic sandy soils
12	Quarry JERLIDERIE GR 439596	250 m c. 200 ha	as for Site 11	as for Site 11
13	Berrigan JERILDERIE GR 383592	120 m <100 ha	Berrigan Granite: coarse biotite granite	as for Site 11
14	The Boat Hill JERILDERIE GR 397582	182 m <100 ha	as for Site 13	as for Site 11
15	Grong Grong NARRANDERA GR 478712	189 m <100 ha	Grong Grong Granite: medium-grained muscovite-biotite granite	granite; loamy sand
16	Mt Rossi CARGELLIGO GR 421881	380 m >1000 ha	Silurian (?) Ural volcanics: rhyolite, rhyolite breccia, quartz-feldspar porphyry, chert and tuff	geology not confirmed; dark sandy loam
17	Keginni Range IVANHOE GR 336943	c.150 m >1000 ha	Late Devonian Mulga Downs Group: quartzite and sandstone, pebbly to conglomeratic in part, siltstone and shale.	sandstone; soils not investigated
18	Manfred Range POONCARIE GR 748323	176 m c.1000 ha	as for Site 17	no field data
19	Mt Binya NARRANDERA GR 429774	224 m >1000 ha	as for Site 17	sandstone; soils not investigated

dobolin, Cobar and Hay District Technical Manuals (Soil Conservation Service 1974, 1978, 1986) include information on vegetation, geology and soils for outcrops occurring within their districts and the Forestry Commission (1984) describes vegetation types on ranges within the the Griffith Forestry District.

Climate

The region is semi-arid and displays a rainfall and reliability gradient from east to west. Stations at Jerilderie, Narrandera, Griffith and Lake Cargelligo receive an average annual rainfall between 380–420 mm. Keginni Range receives approximately 330 mm whilst Manfred Range in the west receives 263 mm (Bureau of Meteorology 1991). Over the long term rainfall is generally winter dominant although there have been periods when a summer rainfall influence has extended to the NSW–Victorian border (Cunningham et al 1981).

Average temperatures for the area range from the 30 and 35°C for summer maxima with summer minima between 14 and 18°C. Winter maxima are between 13 and 16°C with winter minima between 3 and 5° C (Bureau of Meteorology 1991).

History and land use

Several Aboriginal tribes occupied the region. To the east the Wiradjuri inhabited the plains and waterways such as the Lachlan River, with their territory extending east to the Western Slopes. The Barkindji occupied country east of the Darling River including the Manara Hills, Manfred Range and the Willandra Lakes system (Allen 1979/1980; Central Mapping Authority 1987).

John Oxley explored the area in 1817. On arriving at the base of Mount Narriah (Site 6) he wrote 'The country having been recently burnt, some good grass was found for the horses a little to the south west' (Oxley 1820). On many occasions he makes reference to the presence of Aboriginal people in the region commenting on their behaviour and use of fire. 'Three or four fires were seen in the north west, and recent traces of the natives were discovered near our tents'.

Squatters moved stock into the area from the late 1830s. Land along the river systems was taken up first, and by 1848 there were a number of runs established (Soil Conservation Service 1974). Cattle at first predominated but were later replaced by sheep (Cunningham et al 1981). Wheat had been sown by 1866 and became the major agricultural product at the end of the nineteenth century (Forestry Commission 1984). Mining has occurred particularly north of Lake Cargelligo where copper mining began in the late 1860s; copper and gold mining were reported at the turn of the century between Mount Tinda and Condobolin (Cambage 1901). Granite outcrops to the south of the study area have been quarried for road and railway construction material.

Clearing of the best agricultural lands between about 1880 and 1910 left islands of vegetation on the more infertile and/or inaccessable outcrops and ranges. State Forests were declared over remnant forest and woodlands in the early twentieth century and many are associated with the range system and include the Lachlan and Melbergen Ranges, the Naradhan Range and associated Jimberoo Creek area. Apart from the economic value of the timber the state forests are used for recreation, education, apiary and grazing (Forestry Commission 1984).

Methods

Potentially rocky areas were identified from the 1:250 000 geological maps, Cargelligo, Narrandera, Jerilderie, Ivanhoe (Geological Survey of New South Wales various dates) and the 1:500 000 Wentworth sheet (1971). The presence of natural vegetation and the isolation and accessibilty of these rocky areas were determined from photomosaics (New South Wales Department of Lands 1:50 000 Photomap Series).

Field inspection of a representative range of rocky outcrops was carried out. Four major geological types were sampled; sandstones (Cocoparra Group, Mulga Downs Group), granite (Ardlethan Granite, Jindera Granite, Berrigan Granite, Grong Grong Granite), rhyolite (Ural Volcanics) and slate (low grade metamorphics). The term 'geological type' is used in a generic rather than specific sense as the sites comprise various rock strata. For most sites geology was confirmed in the field (Table 1). Many promising geological areas were seen on the photomosaics to be heavily disturbed and were not visited. This was particularly so for areas of low relief in the south on Ordovician sediments and Silurian granites. Other potential sites deemed worthy of sampling were visited but not sampled because of their obvious clearing of the understorey for pasture; for example, Mount Arthur (NARRANADERA 487694), Mullemblah Hill (JERILDERIE 476059) and Blue Hill (JERILDERIE 489067).

The vegetation of each outcrop was recorded from 20 x 20 m quadrats and traverses. To cover the full range of habitat diversity, quadrats were located on different topographic positions to sample variations in aspect and slope. Up to three quadrats were recorded at a site depending on area and disturbance. In each quadrat floristic composition (both native and exotic), structure (tree height and number of strata) and species abundance (with an abundance scale of frequent, common, occasional and rare) were recorded. In highly disturbed areas with little variation, species were recorded along traverses with brief notes on structure. Most of the data were collected during October 1986 (Sites 2–16). Data from Site 1 was collected in June 1989, Site 17 in June 1988, Site 18 in October 1983, and Site 19 in October 1989.

TWINSPAN (two-way indicator species analysis) (Gauch 1982) was used to group Sites 2-16 according to similarities in species composition. Sites 2–16 were used for the numerical analysis as the data were collected at the same time minimising seasonal variation. A total of 248 species comprised the data set. Ordination of the species across sites using the program DECORANA (detrended correspondence analysis and reciprocal averaging) (Gauch 1982) was used as an aid to determine the potential effects of environmental gradients.

Results and discussion

From the nineteen sites and four geological types (sandstone, granite, slate and rhyolite) 338 species were recorded (Appendix) representing 67 families, the dominant being Asteraceae (54 species) and Poaceae (44 species). A total of 25 species were trees, 56 species were shrubs and 257 were ground species. 55 exotic species were recorded, 17 from the Poaceae.

Geological influence

Moore (1953) reported little correlation between vegetation and geological type, explaining that some vegetation alliances develop equally well on soils derived from differing substrates and similar substrates of differing geological ages. In considering dominant tree species this study showed general agreement with Moore (Table 2).

Table 2. General vegetation recorded at each site.

1 Mt Bingar
Low open-woodland: *Callitris endlicheri* and *Eucalyptus sideroxylon*. Mixed shrubby understorey dominated by *Melaleuca erubescens*, *Grevillea floribunda* and *Calytrix tetragona*.

2 Jimberoo Creek State Forest
Lower slopes dominated by a low open-woodland of *Eucalyptus macrorhyncha*, *E. dwyeri* and *Callitris glaucophylla*. *E. dwyeri* and *Acacia doratoxylon* on ridges. Understorey comprising regenerating shrubs after recent fire (1985).

3 McPhersons Range
Low open-woodland: *Eucalyptus populnea*, *E. dwyeri* and *Acacia doratoxylon*. Dense patches of *Allocasuarina verticillata* amongst *Acacia doratoxylon*. Open grassy understorey .

4 Flagstaff Hill
Low open-forest: *Callitris endlicheri*, occasional *Eucalyptus dwyeri* and *Acacia doratoxylon*. Herbaceous understorey. *Eucalyptus sideroxylon* frequent on slopes with the understorey dominated by dense *C. endlicheri* regeneration.

5 Lachlan Range
Lower slopes a low open-woodland of *Eucalyptus dwyeri* and *Callitris glaucophylla* with a herbaceous understorey (grazed). Steep slopes dominated by a shrubland of *Beyeria viscosa* amongst boulders. Summit dominated by *Acacia doratoxylon*, understorey herbaceous to shrubby (grazed).

6 Mt Narriah
Low open-woodland: *Eucalyptus dwyeri*, *Acacia doratoxylon* and *Callitris glaucophylla*. Shrubby understorey dominated by *Grevillea floribunda*, *Teucrium corymbosum*, *Pandorea pandorana* and *Gonocarpus elatus*. Scattered *Eucalyptus sideroxylon* and *Prostanthera ovalifolia*.

7 Mt Bunganbil
Slopes have a low open-woodland dominated by *Eucalyptus dwyeri*, *Acacia doratoxylon* and *Callitris glaucophylla* with a shrubby understorey of *Grevillea floribunda*, *Cassinia laevis*, *Prostanthera nivea*, *Calytrix tetragona* and *Pandorea pandorana*. *Stypandra glauca* and *Helichrysum semipapposum* common. Summit dominated by *E. dwyeri*, *A. doratoxylon* and *Allocasuarina verticillata*, with *S. glauca*, *C. tetragona* and thickets of *Platysace lanceolata*.

8 Mt Wammera
Slopes dominated by *Eucalyptus dwyeri*, *Acacia doratoxylon* and *Callitris glaucophylla*. Herbaceous understorey comprising *Gonocarpus elatus*, *Stypandra glauca* and various grasses. Ridge areas dominated by *E. dwyeri*, *A. doratoxylon* and *Allocasuarina verticillata* with *Stypandra glauca* and *Platysace lanceolata* and scattered *Prostanthera nivea* and *Calytrix tetragona*.

9 Mt Boomanoomana
Open-woodland: *Eucalyptus microcarpa* and *Callitris glaucophylla*, understorey predominantly grasses with occasional shrubs. *Allocasuarina verticillata* common on stony areas. Dense regrowth of *C. glaucophylla* (4–5 m) on the southern aspect.

10 Bald Hill Tank
Low open-woodland: *Eucalyptus dwyeri* and *Acacia doratoxylon*, herbaceous understorey dominated by *Arctotheca calendula*, *Cheilanthes austrotenuifolia* plus various grasses and forbs.

11 Mt Goombargana
Eucalyptus dwyeri low open-woodland on slopes and summit with occasional *Acacia doratoxylon*. *Allocasuarina verticillata* locally common on flat rock shelves, and small pockets of *Eucalyptus albens* occur below the summit. The herbaceous understorey is dominated by *Gonocarpus elatus*, *Geranium* species, *Erodium botrys*, *Stypandra glauca*, *Vulpia bromoides* and *Bromus rubens*.

12 Quarry
Low open-woodland: *Eucalyptus dwyeri* over a herbaceous understorey dominated by grasses and introduced species.

13 Berrigan
Herbaceous stratum only.

14 The Boat Hill
Low open-woodland: *Eucalyptus melliodora, Callitris glaucophylla, Crassula* species, *Erodium* species, various grasses and introduced herbs.

15 Grong Grong
Occasional *Eucalyptus dwyeri, E. populnea* and *Callitris glaucophylla*. Herbaceous understorey.

16 Mt Rossi
Low open-woodland: *Eucalyptus dwyeri* and *Callitris glaucophylla* on the lower slopes with a herbaceous understorey, massive regrowth of young pine. Midslope dominated by *E. dwyeri, Acacia doratoxylon* with occasional *Eremophila longifolia*. Summit carries *E. dwyeri* and *Allocasuarina verticillata* with *Prostanthera nivea, Gonocarpus elatus* and occasional *Microseris lanceolata*.

17 Keginni Range
Low open-woodland: *Eucalyptus intertexta, Callitris glaucophylla* with scattered *Acacia aneura* and *A. doratoxylon*. Understorey shrubby to herbaceous (grazing) with *Acacia decora* and *Cheilanthes austrotenuifolia*.

18 Manfred Range
Open-shrubland: *Acacia brachystachya. Callitris glaucophylla* on escarpment amongst outcropping bedrock, scattered shrubs including *Dodonaea* species. Understorey herbaceous with abundant grasses.

19 Mt Binya
Woodland of *Callitris endlicheri* and *Eucalyptus crebra*. Mixed shrubby understorey with many regenerating *Callitris* species and *Dodonaea* species.

Generally, the lower slopes of outcrops and outcrops of low relief (for example Manfred Range, 176 m) contained the same species as the surrounding country, for example *Callitris glaucophylla*. Outcrops of higher relief (usually greater than 200 m) generally had a low open-woodland structure with two species predominating,*Eucalyptus dwyeri* (68% of sites) and *Acacia doratoxylon* (74% of sites). These two species occurred in a range of habitats at each site and on different geological types.

Tree species did not appear to be influenced by rock type but showed more variation with regard to altitude, soil depth and type and position on slope. *Callitris glaucophylla* commonly occurred especially on the footslopes and on benches where there was greater soil development. *Eucalyptus sideroxylon* occurs sporadically on loamy soils on the footslopes of the larger ranges in the north of the survey area where it often forms extensive stands and dominated the vegetation, for example, in the Lachlan Range State Forest. Low open-forest dominated by *Callitris endlicheri* occurred over the high ridges on stony soils such as in the Lachlan Range.

In contrast the understorey showed strong relations with geological type. On sandstones the understorey comprised a dense to open shrub strata and a varying cover of herbs and grasses (Table 3). On granite and slate sites the understorey was dominated by grasses and herbs, with shrub species almost completely absent. Mount Rossi (Site 16) on rhyolite had some areas dominated by grasses and herbs but other areas having a prominent shrubby component.

Of the total species recorded, the sandstone sites (with 53 species/site) are significantly richer than the granite sites (with 30 species/site) ($t=3.44$, d.f.=11, $p<0.05$), having a large number of shrubby and herbaceous species (Tables 3 & 4). As only one site each was sampled for the slate and rhyolite lithology no comparison of richness has been made.

Table 3. Total number of trees, shrubs and ground species, and total number of species recorded for the four geological types. Figures in brackets denote number of species confined to individual geology (* denotes one site sampled only).

Geological type	No. trees	No. shrubs	No. ground species	Total
sandstone	18 (11)	49 (41)	189 (118)	256 (170)
granite	10 (2)	4 (-)	96 (40)	110 (42)
slate*	5 (-)	4 (4)	39 (11)	48 (15)
rhyolite*	7 (2)	8 (3)	49 (8)	64 (13)

The number of species restricted to each geological type varied considerably; 66% were confined to sandstone, 38% to granite, 31% to slate and 20% to rhyolite (Table 3).

Numerical classification

Classification and ordination using TWINSPAN and DECORANA for sites 2–16 confirmed differences in the vegetation between the sandstone and granite lithologies (Figure 2). Generally all sandstone sites are grouped together, as are most of the granite sites. For the sandstone sites there appears to be an east-west geographic separation, i.e. the western sites, (3,4,5), are separate from the more easterly sites (2,6,7,8). Climatically, the western sites are slightly drier, and lithologically, the western sites are more similar to each other when compared with the eastern sandstone sites. The granite sites display a north-south geographic separation, probably reflecting factors such as climatic and geological differences. Exceptions to these general trends are Mount Boomanoomana (Site 9), Bald Hill Tank (Site 10) and Mount Rossi (Site 16). Without more detailed field sampling the interpretation of these results is open to speculation.

Significant species

Several rare plants were recorded. *Phebalium obcordatum* (Rutaceae) (coded 3RCa by Briggs & Leigh 1988) was recorded on the summit of Mount Bingar in Cocoparra National Park and Mount Binya in Binya State Forest at the southern end of the Cocoparra Range. It is also known from Yathong Nature Reserve.

Pomaderris cocoparrana (Rhamnaceae) is a newly described species originally included, but distinct from, the widespread species *P. andromedifolia* (Walsh 1990). It has been recorded for Mount Binya (this survey) and Cocoparra National Park. It has been assessed as 2RCat (Walsh 1990).

Although not recorded for this survey *Acacia curranii* (Fabaceae - Mimosoideae) occurs in the vicinity of Shephards Hill north of the study area. This is lithologically similar to Mount Rossi in the Ural Ranges (Site 16) and the species may occur on more inaccessible areas of the ranges further to the south. This species is coded 3V (Briggs & Leigh 1988) as its population is considered vulnerable and is not reserved.

Fifteen species recorded (12 native, 3 introduced) represented extensions of range for the South Western Slopes and South Western Plains (Appendix). Six were recorded for Jimberoo Creek State Forest (Site 2), burnt by wildfire 10 months previous, and includes the unusual occurrence of *Xanthorrhoea glauca* subsp. *angustifolia* (Xanthorrhoeaceae) which has a scattered distribution and is usually found on rocky (lime-

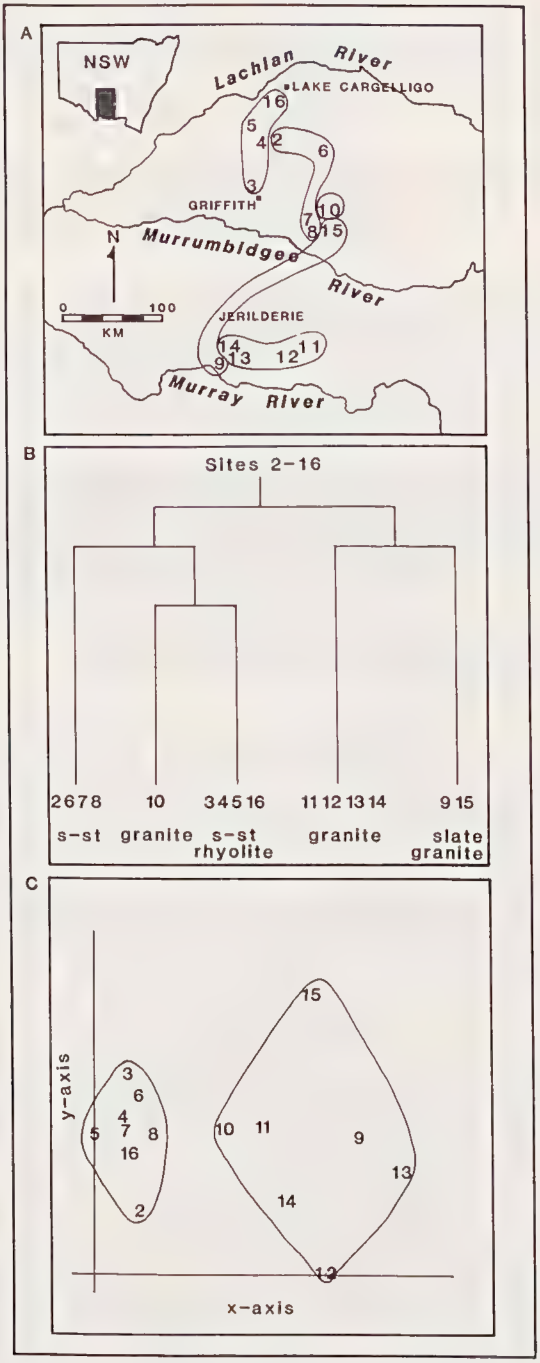

Figure 2. TWINSPAN classification (a & b) and DECORANA ordination (c) for sites 2–16.

Table 4. Geological type, number of sites, mean number of species/site and percentage of introduced species.

Geological type	No. sites	Mean no. species	Mean no. intro. spp.	% introduced species
sandstone sites	11	53 ± 5.09	7	13%
granite sites	6	30 ± 3.8	11	37%
slate site	1	44	9	20%
rhyolite site	1	63	5	8%

stone and trachyte) and gravelly slopes on the Dividing Range further east (Bedford 1988). Jacobs & Lapinpuro (1986) record this species as *X. australis* subsp. *australis* 'western form'.

Disturbance

Most of these rocky outcrops and ranges have been disturbed to varying degrees. Granite outcrops of low relief have been the most affected. Many have been quarried for railway construction, most have active rabbit populations, and some are grazed by sheep. These sites have significantly higher numbers of exotic species (37%) compared with the sandstone sites (13%) ($t=2.59$, d.f.= 11, $p < 0.05$) (Table 4). The sandstone vegetation contains fewer exotic species and disturbance generally is from logging and browsing by goats.

Introduced species

Of the 338 species recorded for this survey 55 (17%) are introduced. Many are species from adjacent agricultural lands. All sites had some exotic species. This infestation ranged from 3 (Site 4) to 14 (Site 14) introduced species. Seven common weed species occur on three of the four geological types, these being *Arctotheca calendula, Hypochoeris glabra* (Asteraceae), *Echium plantagineum* (Boraginaceae), *Aira cupaniana, Briza minor, Bromus rubens* and *Vulpia myuros* (Poaceae).

Feral animals

The predominant feral animal of the outcrops and ranges is the goat (*Capra hirsus*). These are highly selective feeders selecting the most nutritious parts of the plants such as leaves, buds and fruits (Downing & Mitchell 1988). They show a marked preference for browsing small trees and shrubs, but eat grasses and other herbs during drier times (Breckwoldt 1983). Their diet includes a wide selection of native species and some introduced species. Goats are capable of pulling down branches and will readily climb into bushes, destroying them. Obvious damage in Cocoparra Range includes the breaking down of *Acacia deanei* and *Goodia medicaginea* and the browsing of *Callitris endlicheri* and *Maytenus cunninghamii* (Brickhill pers. comm.). Goats are present in moderate numbers in the Keginni Range (Site 17) and in the Cocoparra Range; they were also recorded for Flagstaff Hill (Site 4), Lachlan Range (Site 5), Mount Bunganbil (Site 7), Mount Goombargana (Site 11) and Manfred Range (Site 18).

Rabbits (*Oryctolagus cuniculus*) were noted on sites where the soils are deeper and topography less rugged, particularly on granites in the south including The Boat Hill (Site 14) and also on the McPherson and Manfred Ranges (Site 3 and 18 respectively). Friable soils to a depth of 75 cm or more are favourable for warren construction (Parer & Libke 1985). First introduced to Australia in the late 1850s, they have multiplied and spread throughout much of southern Australia, becoming the most damaging pest in the country (Breckwoldt 1983). Although population numbers were greatly reduced by the introduction of myxomatosis during the 1950s, population numbers are again on the increase.

Rabbits can physically damage shrubs and trees through direct grazing and ringbarking, and overgrazing of both herbs and shrubs together with the effects of burrowing can lead to severe erosion and habitat destruction.

Fire

Only one site, Jimberoo Creek State Forest (Site 2), showed evidence of a recent fire (1985) which was both crown scorch and combustion particularly on the ridge areas (Jolly pers. comm.). Mount Goombargana (Site 11) has carried a wildfire some years previously (Packer pers. comm.) as have areas of the Cocoparra Range. Other large range areas would be expected to carry fire at some time. On many of the smaller outcrops there did not appear to be any evidence of fire. This may be a result of their small area, isolation and/or the open nature of the vegetation. Alterations to the natural fire regimes result from fragmentation through land clearing (Hobbs 1987) and management (forestry, mining and reserves).

Conservation and management

Major conservation reserves in the south western slopes and plains relevant to this study include Yathong Nature Reserve (NR), Nombinnie NR, Mount Bootheragandra NR, Cocoparra NR and National Park, The Rock NR and Mount Galore. Most of these reserves are on sandstone lithology. Plant communities occurring on granite and rhyolite geological types are not represented in any reserves and many are privately owned.

Representative vegetation communities on granite lithology are worthy of protection. The smaller, more isolated granite outcrops in the south of the study area are heavily disturbed. Continued disturbance, isolation and the resulting lack of corridors for species dispersal and reproductive success suggests that these small isolated outcrops will continue to degenerate (Hobbs 1971). Protection of larger areas are necessary if long-term viability is to be maintained.

Control of introduced animals, weed invasion, land use and to a certain degree, fire, are management concerns for conservation areas.

Other rocky outcrops

As a reconnaissance survey it has not been possible to visit all rocky outcrops in the south west and further work on additional sites needs to be done. The significance of the slate and rhyolite sites (9 and 16) requires further sampling. Vegetation on the Manara Hills and Darnick Ranges in the west of the study area is of interest to compare with Keginni and Manfred Ranges (Sites 17 and 18 respectively). Other areas of interest are the olivine leucitite outcrops, a Tertiary alkali basalt, at Mount Melbergen in the Melbergen Ranges west of Rankins Springs, and areas west of Lake Cargelligo.

Conclusion

This study has shown the significance of the vegetation on the outcrops and ranges. The vegetation is characteristic for geological type particularly for sandstone and granite. Although having some tree species in common, sandstones sites are richer in understorey species and have a large shrub component. In contrast granite sites have fewer species most of which are herbaceous.

Of the four geological types, all have species restricted to individual geologies (between 20% and 66%). Many of these outcrops and ranges represent islands of native vegetation amongst extensive tracts of agricultural land and conservation on a variety of vegetation and geological types should be undertaken.

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APPENDIX

Species recorded from sites on rocky outcrops and ranges in south-western NSW (q = quadrat; t = traverse).

Site:

1 Mt Bingar, Cocoparra National Park (qt)
2 Jimberoo Creek State Forest (qt)
3 McPhersons Range (t)
4 Flagstaff Hill, Lachlan Range State Forest (q)
5 Lachlan Range (qt)
6 Mt Narriah (qt)
7 Mt Bunganbil (qt)
8 Mt Wammera (qt)
17 Keginni Range (t)
18 Manfred Range (t)
19 Mt Binya, Binya State Forest (qt)

9 Mt Boomanoomana (t)

10 Bald Hill Tank (t)
11 Mt Goombargana (qt)
12 Quarry N of Corowa (t)
13 Berrigan (t)
14 The Boat Hill (t)
15 Grong Grong (t)

16 Mt Rossi (qt)

* introduced species
# new record for New South Wales
! extension of known range in New South Wales
? query on identification

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
PTERIDOPHYTES																			
Adiantaceae																			
Cheilanthes austrotenuifolia	1	2	3	4	5	6	7	8	17	18	19	9	10	11					16
C. distans							7			18	19								
C. sieberi subsp. *sieberi*	1									18	19								
Pleurosorus rutifolius	1		3		5	6	7		17	18	19								
P. subglandulosus														11					
GYMNOSPERMS																			
Cupressaceae																			
Callitris endlicheri	1	2				6		8											
C. glaucophylla	1	2				6	7	8		18		9	10						16
ANGIOSPERMS																			
Amaranthaceae																			
Ptilotus atriplicifolius subsp. *atriplicifolius*					5														
P. gaudichaudii var. *parviflorus*										18									
P. nobilis										18									
P. polystachyus										18									
P. spathulatus																			16
Anthericaceae																			
Arthropodium minus	1		3									9							
Thysanotus patersonii		2	3			6		8				9	10	11					16
Tricoryne elatior	1																		
Apiaceae																			
Daucus glochidiatus	1	2	3	4	5	6	7	8				9					14		16

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
!Hydrocotyle callicarpa								8											
H. laxiflora	1																		
Platysace lanceolata	1	2		4		6	7	8											
Trachymene cyanopetala			3				7	8											
T. ornata					5														16
Apocynaceae																			
Parsonsia eucalyptophylla			3			6	7			18	19								16
Asphodelaceae																			
Bulbine bulbosa					5								10						
B. semibarbata		2	3	4	5		7	8		18	19		10						16
Asteraceae																			
Actinobole uliginosum		2	3	4	5	6		8					10				14	15	16
**Arctotheca calendula*		2	3			6	7	8				9	10	11	12	13	14	15	
**Bidens pilosa*					5		7												
Brachycome ciliaris																			
subsp. *ciliaris*										18									
subsp. *lanuginosa*										18									
B. ciliocarpa						6													
B. diversifolia								8											
B. perpusilla var. *tenella*								8											
Calotis cuneifolia	1	2			5				17		19								
C. hispidula			3						17										
Cassinia arcuata												9							
C. laevis	1	2	3		5	6	7	8											16
!C. uncata		2																	
**Centaurea melitensis*										18									
!Ceratogyne obionoides				4															
Chrysocoryne pusilla										18									
Chthonocephalus pseudevax				4	5														16
**Conyza albida*	1																		
**C. bonariensis*		2																	
Cotula australis															12				
Craspedia sp. O										18									

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Gnaphalium sphaericum		2								18									
Helichrysum ambiguum										18									
H. apiculatum	1									18	19		10					15	16
H. bracteatum		2	3																
H. semipapposum	1						7												
H. viscosum		2	3			6	7	8			19			11					16
Helipterum demissum				4															
H. diffusum					5		7			18									16
H. jessenii			3				7												
H. moschatum										18									
H. polygalifolium										18									
H. pygmaeum			3							18									
**Hypochoeris glabra*	1	2	3	4	5	6	7	8		18		9		11	12		14	15	
**H. radicata*		2					7												
Isoetopis graminifolia			3																16
Microseris lanceolata																			16
Millotia myosotidifolia			3	4	5	6	7	8		18									16
Minuria leptophylla			3															15	16
Myriocephalus rhizocephalus																13			
**Onopordum acanthium*																	14		
Podolepis arachnoidea				4															
Pseudognaphalium luteo-album												9							
Senecio anethifolius					5														16
S. quadridentatus	1	2				6	7	8						11			14		
Sigesbeckia australiensis										18									
S. orientalis									17										
**Sonchus oleraceus*	1				5	6	7	8											16
Stuartina hamata										18									
S. muelleri	1	2	3	4	5	6	7	8	17				10	11	12	13	14		16
Triptilodiscus pygmaeus		2		4	5		7	8			19		10	11			14		16
Vittadinia condyloides										18									
V. dissecta var. *hirta*											19								
V. gracilis												9						15	
Bignoniaceae																			
Pandorea pandorana			3		5	6	7												16

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Boraginaceae																			
Cynoglossum australe										18									
**Echium plantagineum*			3									9	10				14	15	
!Myosotis australis		2																	
**Plagiobothrys canescens*														11	12		14		
Brassicaceae																			
Geococcus pusillus									17										
Harmsiodoxa blennodioides	1				5														16
Lepidium papillosum					5														
Pachymitus cardaminoides		2	3																
Brunoniaceae																			
Brunonia australis											19								
Campanulaceae																			
Wahlenbergia communis										18									
W. gracilenta		2	3				7			18									
W. luteola													10						
W. stricta		2	3			6	7	8			19	9							16
Caryophyllaceae																			
**Cerastium glomeratum*		2																	
**Petrorhagia nanteuilii*											19								
**P. velutina*														11	12		14		
**Silene gallica*					5				17		19								
**S. nocturna*			3								19								
**Stellaria media*									17										
Cassythaceae																			
Cassytha melantha	1																		
Casuarinaceae																			
Allocasuarina verticillata		2		4		6	7	8				9		11					16
Casuarina pauper										*18*									

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Chenopodiaceae																			
Atriplex semibaccata												9?							
Chenopodium desertorum																			
subsp. *anidiophyllum*																		15	
subsp. *microphyllum*								8											
**C. murale*									17	18									
Einadia hastata												9?							
E. nutans	1		3								19						14	15	
Maireana enchylaenoides																13			
M. humillima																			16?
Sclerolaena birchii								8											
S. convexula										18									
Convolvulaceae																			
Convolvulus erubescens																			16
Crassulaceae																			
Crassula colorata																			
var. *acuminata*	1														12		14		16
C. decumbens																			
var. *decumbens*													10		12			15	
C. sieberiana		2								18									
Cyperaceae																			
Carex inversa												9							
Fimbristylis dichotoma	1								17										
!*Isolepis marginata*		2																	
Lepidosperma laterale s.l.								8				9							
Dilleniaceae																			
Hibbertia obtusifolia	1	2				6													
H. riparia								8											
H. sericea	1	2																	
Droseraceae																			
Drosera glanduligera												9							

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Drosera peltata	1	2											10					15	
D. sp.																	14		
Epacridaceae																			
Astroloma humifusum	1																		
Melichrus urceolatus	1							8											
Euphorbiaceae																			
Beyeria viscosa					5														
Chamaesyce drummondii s.l.	1									18									
Phyllanthus fuernrohrii									17	18									
P. hirtellus form b	1																		
P. hirtellus		2					7	8											
Fabaceae-Caesalpinoideae																			
Senna artemisioides																			
nothosubsp. *artemisioides*											19								16
subsp. *filifolia*											19							15	
Fabaceae-Faboideae																			
Daviesia mimosoides																			
subsp. *virgata*												9							
D. ulicifolia							7												
Dillwynia sericea												9							
Goodia medicaginea		2																	
Glycine canescens	1																		16
G. sp.					5														
Hardenbergia violacea	1																		
Indigofera australis	1		3			6	7	8			19		10	11			14		16
Lotus cruentus											19								
**Medicago laciniata*									17										
**M.* sp.	1																		
Mirbelia pungens							7												
Swainsona procumbens															12				
Swainsona oroboides subsp. *sericea*		2																	

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
**Trifolium arvense*											19				12	13			16
**T. subterraneum*												9			12				
**T. tomentosum*											19								
Fabaceae-Mimosoideae																			
Acacia acinacea												9							
A. amblygona		2																	
A. aneura									17										
A. brachystachya										18									
A. burkittii										18									
A. deanei subsp. *deanei*								8									14		
subsp. *paucijuga*	1										19								
A. decora											19							15	
A. doratoxylon	1		3	4	5	6	7	8	17		19		10	11			14	15	16
A. implexa																	14		
A. ligulata										18									
A. paradoxa	1	2																	
A. pycnantha												9							
Fumariaceae																			
**Fumaria bastardii*														11					
**F. capreolata*															12				
**F. densiflora*													10						
**F. muralis*														11					
Geraniaceae																			
**Erodium botrys*												9							
E. cicutarium														11			14		
E. crinitum														11		13	14		
**E. moschatum*															12				
Geranium retrorsum													10				14		
G. solanderi																			
var. *solanderi*		2												11	12				
G. sp.	1																		

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Goodeniaceae																			
Dampiera lanceolata var. *lanceolata*	1	2		4				8			19								16
Goodenia fascicularis			3																
G. glabra	1										19								
G. heteromera			3																
G. ovata	1																		
!G. stephensonii																			16
!Velleia arguta					5														
V. paradoxa																		15	
Haloragaceae																			
Gonocarpus elatus	1	2	3	4	5	6	7	8	17	18	19	9	10	11			14	15	16
!Myriophyllum simulans																13			
Hypoxidaceae																			
Hypoxis glabella														11					
Iridaceae																			
**Romulea rosea* var. *australis*												9						15	
*#*Sparaxis pillansii*																		15	
Juncaceae																			
Juncus subsecundus												9					14		
J. sp.		2																	
!Luzula flaccida																	14		
L. meridionalis														11					
Lamiaceae																			
Ajuga australis		2			5									11					16
Prostanthera nivea			3				7	8			19								16
P. ovalifolia				4		6	7												
P. striatiflora										18									
Teucrium corymbosum						6													

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Lobeliaceae																			
Isotoma axillaris								8	17					11					
Loganiaceae																			
Mitrasacme paradoxa							7												
Lomandraceae																			
Lomandra multiflora			3			6	7					9						15	
L. patens	1										19								
L. sp.								8											
Malvaceae																			
Abutilon sp.					5														
Sida calyxhymenia			3		5														16
S. filiformis	1									18									
S. petrophila											19								
Myoporaceae																			
Eremophila longifolia																			16
E. mitchellii					5														
E. sturtii										18									
Myrtaceae																			
Calytrix tetragona	1	2		4		6	7	8											
Eucalyptus albens														11					
E. dwyeri	1	2	3	4	5	6	7	8					10	11	12			15	16
E. vicina									17										
E. intertexta									17	18									
E. macrorhyncha	1	2																	
E. melliodora																	14		
E. microcarpa												9		11?					
E. morrisii									17										
E. populnea subsp. *bimbil*			3										10					15	
E. sideroxylon	1					6													
E. viridis																			16

	Sandstone											**Slate**	**Granite**						**Rhyolite**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Leptospermum divaricatum	1	2									19								
Melaleuca erubescens	1					6													
Orchidaceae																			
Caladenia carnea				4			7	8									14		
C. dilatata		2	3																
Calochilus robertsonii		2						8											
Diuris maculata						6		8											16
Glossodia major							7	8											
Pterostylis biseta								8?											
P. mutica			3	4			7												16
P. nana	1																		
P. sp.	1						7					9							
Oxalidaceae																			
Oxalis corniculata		2	3	4	5		7	8											
O. perennans												9							
**O. pes-caprae*														11				15	
O. radicosa	1													11	12				
O. sp.																			
Papaveraceae																			
**Papaver aculeatum*		2																	
Phormiaceae																			
Dianella sp.	1					6												15	
Stypandra glauca	1	2					7	8					10	11					
Pittosporaceae																			
Bursaria spinosa																			16
Pittosporum phillyreoides																			16
Plantaginaceae																			
Plantago drummondii										18									
P. turrifera										18									

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Poaceae																			
*!*Aira caryophyllea*		2									19								
**A. cupaniana*							7	8				9?		11		13	14		16
**A. sp.*		2	3	4	5	6		8					10						16
**Alopecurus geniculatus*																13			
Aristida behriana	1																		
A. jerichoensis																			
subsp. *jerichoensis*	1																		
subsp. *subspinulifera*													10						
A. sp.									17										
**Avena barbata*																		15	
**Briza maxima*																		15	
**B. minor*		2										9					14	15	
Bromus arenarius					5					18									
**B. diandrus*																	14		
**B. hordeaceus*													10?				14		
**B. rubens*		2			5	6	7	8		18			10	11	12	13	14	15	16
Danthonia caespitosa		2					7	8?			19	9							16
D. eriantha				4?				8											
D. setacea											19								
Digitaria brownii	1									18									
Elymus scabrus													10						16
**Hordeum leporinum*		2													12				
Eragrostis dielsii										18									
E. lacunaria									17										
**Lamarckia aurea*			3		5		7	8	17	18									
**Lolium perenne*																		15	
**Lophochloa pumila*										18									
Monachather paradoxa										18									
Neurachne munroi			3				7												
*!*Periballia minuta*												9							
Poa annua															12				
P. labillardieri								8											
P. sieberiana																			
subsp. *sieberiana*								8				9							
Stipa acrociliata	1																		

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Stipa blackii										18									
S. densiflora											19	9							
S. mollis			3		5	6	7	8						11					
S. nitida										18									
S. nodosa										18		9	10		12		14		
S. scabra subsp. *scabra*	1											9							
subsp. *falcata*		2	3	4		6								11				15	
S. setacea			3											11					
Thyridolepis mitchelliana	1		3	4	5	6			17	18	19								16
**Vulpia bromoides*				4		6							10	11		13			
**V. myuros*		2	3		5		7	8		18	19		10		12		14		16
Polygonaceae																			
**Polygonum arenastrum*																13			
Rumex brownii											19				12?				
R. dumosus																	14		16
Portulacaceae																			
Calandrinia calyptrata																	14		
C. eremaea										18		9					14		
C. sp.	1								17										
Proteaceae																			
Grevillea floribunda	1	2				6	7	8											
Hakea tephrosperma			3		5														
Ranunculaceae																			
Ranunculus lappaceus		2																	
R. pentandrus																			
var *platycarpus*																			16
R. sessiliflorus																			
var. *sessiliflorus*		2						8		18							14		
var. *pilulifer*													10						

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Rhamnaceae																			
Cryptandra amara var. *floribunda*	1																		
Pomaderris cocoparrana	1																		
Rosaceae																			
Aphanes australiana																			16
Rubiaceae																			
**Galium aparine*										18									
G. gaudichaudii					5		7	8				9							
**G. murale*															12		14		
Rutaceae																			
Correa glabra						6													
Eriostemon difformis subsp. *difformis*																			16
E. linearis									17	18									
E. myoporoides subsp. *acutus*		2	3	4			7												
Geijera parviflora										18									
Phebalium obcordatum	1										19								
Zieria cytisoides							7												
Santalaceae																			
Exocarpos cupressiformis	1	2				6	7	8				9							
Sapindaceae																			
Alectryon oleifolius subsp. *canescens*											18								
Dodonaea boroniifolia											19								
D. viscosa																			
subsp. *cuneata/angustissima/ spatulata*	1					6		8											
subsp. *spatulata*								8											

	Sandstone											Slate	Granite						Rhyolite
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Scrophulariaceae																			
Limosella curdieana																13			
**Parentucellia latifolia*												9				13	14		
Veronica plebeia												9							
Solanaceae																			
Cyphanthera albicans subsp. *tomentosa*							7												
Nicotiana simulans										18									
N. suaveolens	1																14		16
!Solanum cleistogamum																			16
S. esuriale										18									
S. ferocissimum					5					18									16
**S. nigrum*										18				11	12				
Stackhousiaceae																			
Stackhousia monogyna		2	3				7				19								16
Sterculiaceae																			
Brachychiton populneus subsp. *trilobus*								8										15	16
Stylidiaceae																			
!Levenhookia dubia						6	7												
Thymeleaceae																			
Pimelea linifolia subsp. *linifolia*											19								
P. trichostachya										18									
Urticaceae																			
Parietaria debilis						6									12				
**Urtica urens*															12				
Violaceae																			
Hybanthus monopetalus	1	2	3	4		6	7	8	17		19								16

	Sandstone											**Slate**	**Granite**						**Rhyolite**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**17**	**18**	**19**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Xanthorrhoeaceae																			
!Xanthorrhoea glauca subsp. *angustifolia*		2																	
Zygophyllaceae																			
Zygophyllum ammophilum										18									
Z. eremaeum										18									
Total number of species	71	68	54	30	44	47	61	64	27	71	45	44	31	37	27	14	40	30	64
Number exotic species	4	12	6	3	7	5	7	8	5	9	7	9	8	11	13	8	14	11	7

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The natural vegetation of the Ana Branch – Mildura 1:250 000 map sheet (New South Wales)

Marilyn D. Fox

Abstract

Fox, Marilyn D. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1991. The natural vegetation of the Ana Branch – Mildura 1:250 000 map sheet (New South Wales).* Cunninghamia *2(3): 443–493.* A vegetation map of the Ana Branch and New South Wales portion of the Mildura 1:250 000 topographic maps (SI 54-7 and SI 54-11) is presented. The area is in semi-arid south-eastern Australia (lat. 33°S and south to the Murray River, long. 141°–142°30′E). The vegetation is described and related to soils and geomorphology. A total of 299 species have been recorded from a variety of communities which comprise fifteen map units. Although there are several significant plant communities in the region that are inadequately reserved and seven species are known to be rare or endangered, less than 1% of the area (19,000 km²) is currently in a formal conservation reserve.

Introduction

Location

The Ana Branch – Mildura map comprises the Australian topographic 1:250 000 Ana Branch sheet (SI 54-7) and the New South Wales portion of the adjacent Mildura sheet (SI 54-11). Figure 1 shows the location of the study area in south-western New South Wales. Although the accepted spelling of the noun anabranch, meaning an alternative or subsidiary course of a river, is as one word, the name of the map sheet is two words. The latter will only be used when referring to the actual map sheet. Figure 2 shows the relevant section of the 1:250 000 map grid, the major rivers and place or homestead/station names. The western boundary of the map is the NSW – South Australian border (141°00′E) while the eastern boundary is 142°30′E which runs just west of Pooncarie to just east of Tarpaulin Bend on the Murray River. The northern boundary is 33°00′S which runs through 'Loch Lilly' near the South Australian border to just north of 'Cuthero' on the Darling River. The southern boundary is the Victorian border along the Murray River, and although politically the border is taken as the southern bank of the river, the vegetation is mapped to the southern extent of the riverine forest. All of the mapped area (with the exception of the Victorian riverine forest) falls within the Western Division of New South Wales. The total area of the map sheet is approximately 19 000 km².

The dominant features of the mapped area are the major rivers, the River Murray which flows from the eastern Great Divide to empty into the sea at the Coorong, South Australia and the Darling flowing down from the far north. The divergence of the Darling and its Great Anabranch is only 12 km north of the map. The Darling meets the Murray at Wentworth, the Anabranch follows a more direct southerly bearing and joins the Murray 15 km west of the Darling–Murray confluence.

The many lakes associated with the Anabranch are an important feature of the landscape of this region. Most of the lakes are dry and, after ephemeral flooding,

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some are opportunistically cropped. One of them, Nearie Lake is a Nature Reserve. There is only one lake associated with the Darling River segment covered by this map, it is small Yartla Lake west of Coona Point. The only lakes associated with the River Murray across the Mildura sheet are Lake Victoria in the far west and the Gol Gol swamp and Lake Gol Gol near Mildura.

The principal road north and south is the Silver City Highway which follows the course of the Anabranch and then continues northwards to Broken Hill. The Sturt Highway follows the course of the Murray from the east to the large regional centre of Mildura in Victoria. It then continues due west south of the river. The area is criss-crossed with minor roads and station tracks, most of which are shown on the topographic sheet. A measure of the relative remoteness of this region is that there are no towns on the Ana Branch sheet and only small settlements on the northern bank of the Murray River.

The area is very flat; the average slope is of the order of 1–2 cm /km (Shiel 1980). In general the terrain slopes downwards from north to south and east to west. The regional relief is flat but there are local high and low features. The 250 ft (76 m) contour cuts through the top northwestern corner of the map. Spot elevations printed on the topographic map are Travellers Lake 150 ft (46 m), Nearie Lake 123 ft (38 m) and at the top of Lake Victoria, 102 ft (31 m). The highest point is The Nob 18 km east of Nearie Lake at 176 ft (54 m).

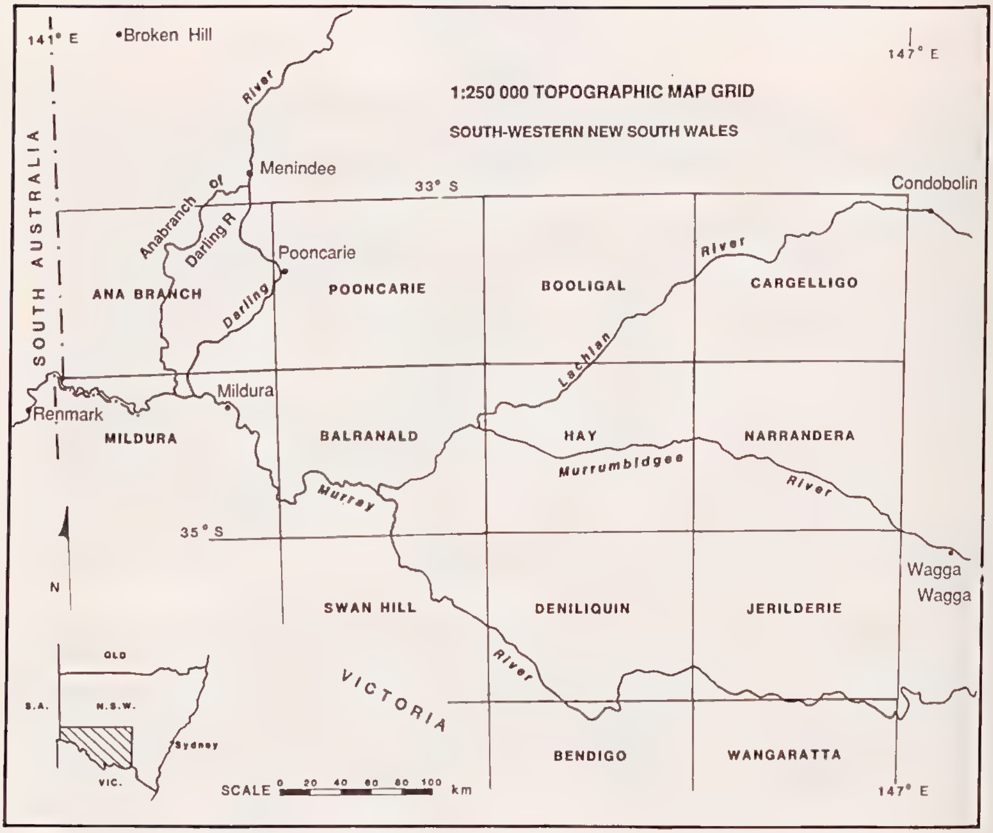


Figure 1. Part of the 1:250 000 map grid showing the mapped sheets and those adjacent to them.

Tectonic history

The entire map area is enclosed within the Murray Basin, a structural basin of 135,000 km^2 evolved from a Tertiary epicontinental basin and Mesozoic and Permian infrabasins (Scheibner 1974). The effective basement of the basin was built in the west by the Adelaide and Kanmantoo Fold Belts and in the east by the Lachlan Fold Belt. There are major faults on the northern and western margins. The study area does not

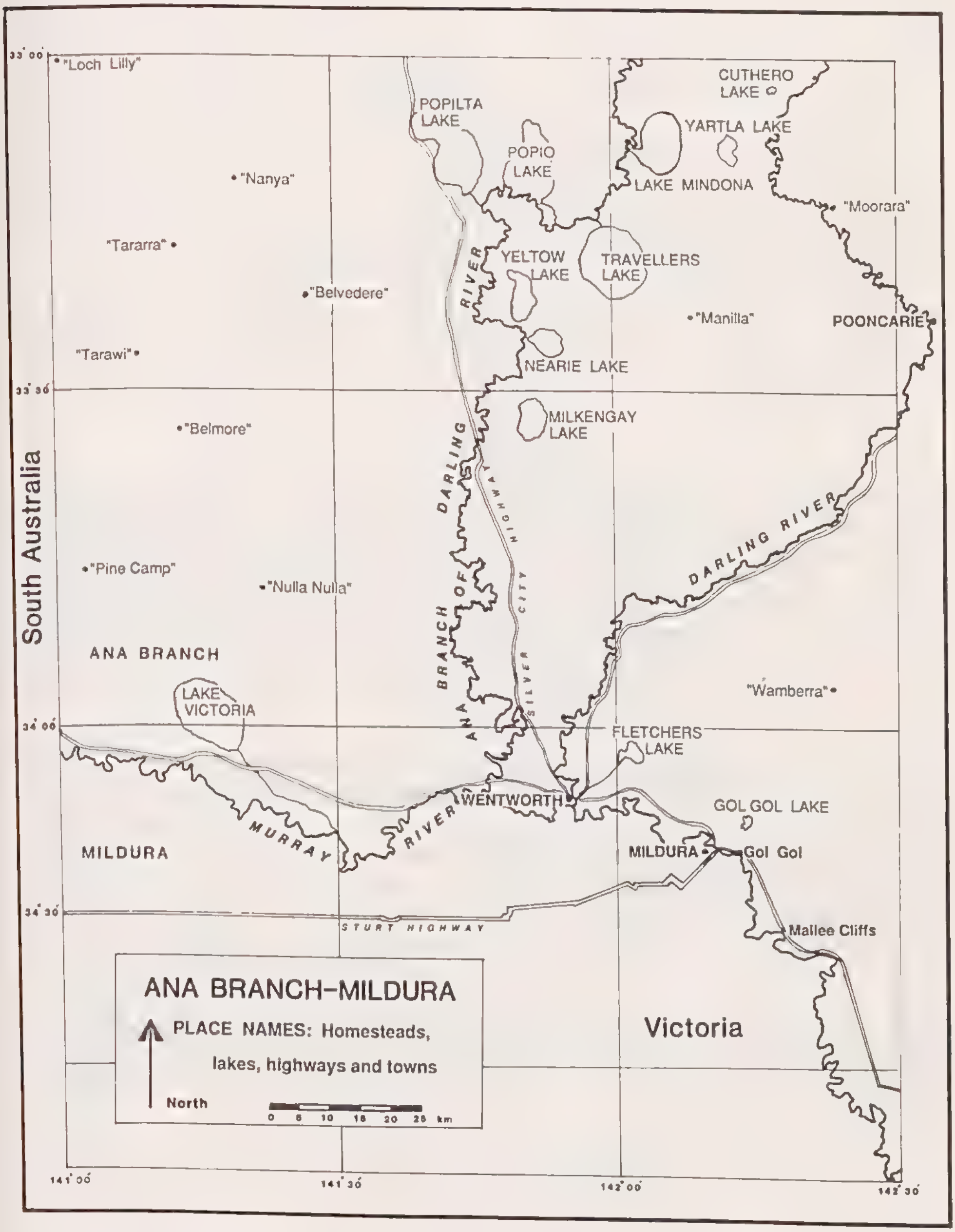


Figure 2. The mapped area comprises two 1:250 000 sheets: Ana Branch and the northern half of Mildura. Major highways, towns and homesteads are shown.

contain any rocky hills or ridges. North of the northern border (south of Broken Hill) there are Cambrian and Precambrian rocks.

The present configuration of the basin has been caused by subsidence and then active sedimentation during the Cainozoic Era. The sediments are extremely thick. A drill-hole near Lake Victoria penetrated bedrock at a depth of 677 m, while nearer Wentworth another went through Permian shale with sand lenses to a conglomerate base at 650 m depth (Pels 1969). On the eastern edge of the Basin are deposits of Tertiary lignites and non-marine, carbonaceous clays up to 360 m thick (Martin 1984). The present landform is a relict Quaternary landform and the contemporary rivers have had little impact (Pels 1969).

The present surface of the mapped area is of entirely Quaternary deposits, principally sands and clays. There are some gypsum deposits near the junction of the Great Anabranch and the Murray. In the far south-west there are some Tertiary outcrops along the Murray River (Pels 1969). A provisional geological map is available (H.N. Ray 1988). The predominant stratigraphy is of Quaternary material comprising fluvial and aeolian deposits. The only other older material are some isolated outcrops of Tertiary sands associated with Murray River and Darling River cliffs.

There are three major aquifers in the sediments of the Murray Basin; these represent glacial peaks and the interbedded clays represent the interglacials (Pels 1969). The hydraulic gradients indicate a general westward and south-westerly direction of groundwater movement.

Palaeohistory

The low-lying area now referred to as the Murray Basin was inundated by shallow marine incursions in the Miocene. These marine transgressions extended as far east as the Willandra lakes (Bowler & Magee 1978). In the Murray Basin the final regression was in the lower Pliocene (Bowler 1982). Following this stage the Murray River was dammed in eastern South Australia producing a large lake, Lake Bungunnia (Firman 1965). The study area falls within the presumed extent of Lake Bungunnia. Palaeomagnetic studies indicate that Lake Bungunnia drained perhaps 700,000 years ago (Bowler 1980a). This would have led to the reworking of the saline basins by both wind and water leading to the present-day aeolian, fluvial and lacustrine landforms.

Over the last major glacial cycle covering the last 120,000 years the south-western region experienced profound changes with the changing precipitation and temperature regimes. From 50,000 to 25,000 years B.P., the increased runoff with reduced evaporation resulted in high groundwater levels and full lakes. About 25,000 years ago the wet phase ended and the lakes shrank and became shallow, saline environments (Bowler 1980a, 1980b). This stage saw the reworking of lake-bed deposits to produce the clay-rich gypseous dunes or lunettes associated with the lakes. At the same time the longitudinal sand dunes were reactivated (Bowler 1976); the last major phase of dune growth was about 15,000 years ago (Bowler 1982). Maximum aeolian activity coincided with the height of glaciation 18,000–16,000 years B.P. (Bowler 1980b, 1982). This extensive aeolian erosion and deposition period, spanning approximately 10,000 years, is the last phase of the shaping of the present-day mallee landforms of the study area.

In the period 15,000 to Present there have been minor oscillations in the hydrologic budget but their effects on landscape development have been subdued. This period saw a general trend to dune stabilisation.

Palaeovegetation

The Miocene-Pliocene interval saw the expansion of the Myrtaceae, Chenopodiaceae and grasslands, together with the contraction of the rainforests (Singh 1982). Myrtaceous fruits occur in Miocene macrofossils, including *Eucalyptus*, *Leptospermum*, *Melaleuca*, *Callistemon* and *Angophora* (Lange 1978). Rainforest with *Nothofagus brassii* persisted in western New South Wales until the end of the Miocene and then was replaced by vegetation rich in Myrtaceae and Casuarinaceae (Martin 1978). The only Pleistocene assemblages found contain much chenopod and composite pollen (Martin 1978), although elsewhere this more open vegetation made its first appearance in the late Pliocene (Truswell & Harris 1982).

Over the past 50,000 years there has been a relationship between high lake levels and high densities of sclerophyll tree vegetation (Dodson 1977). A rise in lake levels 10,000 years ago saw the replacement of eucalypt woodlands by *Allocasuarina verticillata*, and elsewhere *Melaleuca* and *Leptospermum* expanded at the expense of the more open vegetation.

Geomorphology

The present-day landscape is a combination of aeolian, riverine and lacustrine elements. Figure 3 shows the geomorphology of the study area and is based on a map by Bowler and Magee (1978).

The rivers

The major rivers carry water from wetter areas in the north and east, there is no contribution from local surface runoff and hence no eroded channels. Both the Murray and Darling Rivers lose water as they flow westwards. In the past some of the rivers further east, such as the Murrumbidgee, incised prior stream courses and cut over 10 m below the present plain. These incised channels were then filled with Holocene sediments so that now the river beds are only just below the level of the surrounding plain (Pels 1969). Such deposits continue along the Murray River but it is interesting to note that they do not occur along the course of the Darling. The Darling also differs from the Murray and from its own Anabranch by having fewer associated shallow lakes and billabongs. This may reflect a more recent course for the Darling, its previous course being the Great Anabranch.

Linear dunes

These are the stabilised eastern extent of the fossil dunefields of central Australia (Bowler 1980a). The dunes are relatively straight and aligned east-west. They exhibit fairly uniform spacing from 0.2–1.2 km apart and vary in length, but are typically about 3 km long. The linear dunes are quite subdued, commonly with a height differential of only 2–6 m from swale to crest, although in places such as west of the Darling they can be up to 10 m in height. The dunes are composed of reddish-brown sandy clay and sand overlying grey clay. The clay content of the dunes can be as high as 20% in the swales, but is on average half that (Churchward 1963). The carbonate content is on average 5% (Bowler & Magee 1978).

In section the dunes are composed of a series of calcareous palaeosols (Churchward 1961) which represent successive phases of aeolian reactivation. The most recent major phase of dune growth was about 15,000 years ago (Bowler 1982). The long period of stability was maintained by thick vegetation cover. When that was removed by fire and clearing with settlement of the region some of the dunes were reactivated.

Irregular sub-parabolic dunes

These are steep, irregular siliceous dunes, sometimes called jumbled dunes. These are still influenced by prevailing westerly winds so that the apex of the parabola points east. Irregular dunes crests are commonly more than 10 m above the swales and their flanks are steep. Although their spacing is irregular these dunes are closer than the linear dunes. There are some irregular sub-parabolic dunes south of Pooncarie, east of the Darling River.

Sand plains

On the Ana Branch – Mildura map sheet there is a discontinuous belt of sand plain following the Darling and Anabranch and this is typical of the Interactive Zone of Mabbut (1980). This represents the zone of overlap and interaction between the aeo-

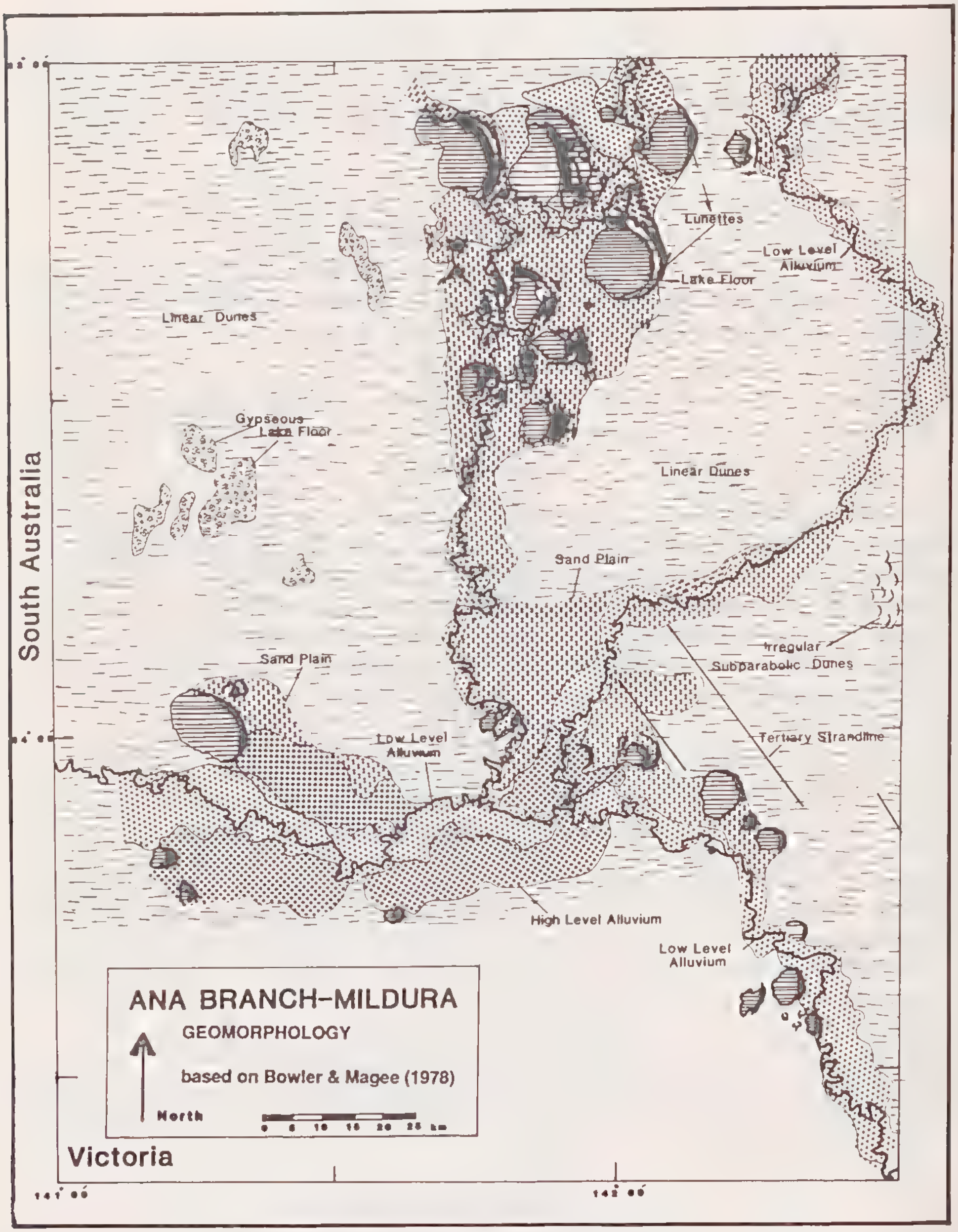


Figure 3. The geomorphology of the mapped area based on a map by Bowler & Magee (1978). The most extensive unit is the linear dunefield. A series of alluvial units is associated with the rivers and lakes.

lian and fluvial systems. It comprises irregular sand accumulations which are roughly circular mounds from less than 100 m to over 3 km in diameter. The larger mounds can be over 30 m in elevation. These are more similar to the linear dunes in composition, comprising sands and sandy clays with layered palaeosols and catenary profile differentiation (Rowan & Downes 1963).

Lunettes

These distinctive structures are smooth crescentic transverse dunes on the eastern and south-eastern sides of lake basins. Lunettes commonly have a 'core' of clean quartz sand which was deposited when the lake was full (e.g. Bowler 1980). Then saline gypseous clay mantled the sand core when the lake dried out. The last episode of lunette building was 19,000–15,000 BP (Bowler & Magee 1978). The lunette height and size is proportional to the size of the lake. On the Ana Branch – Mildura sheet there are well-developed lunettes on Popiltah, Popio and Mindona Lakes, but all the smaller lakes associated with the Anabranch also have defined lunettes. The lunette on Travellers Lake is composed entirely of quartz sand. It never experienced the suitable dry saline conditions necessary to deposit the gypseous clay layer over the sand.

Lake floors

The lakes of the south-west are well defined by the sharp break in slope on their western margin and a lunette on the eastern side. The lakes are typically smoothly elliptical or often kidney-shaped with the long axis aligned roughly north-south.

On the Murray river the principal lake is Lake Victoria near the South Australian border. This is now used as water storage as part of the water conservation-irrigation system of the lower Murray. The Anabranch has an important chain of lakes associated with it which are subject to occasional flooding. However, most of the time the lakes are dry and the lake floors comprise fine-grained clays with silts and sands more prominent in the deposits of the eastern down-wind margins. The dry lake floors are commonly criss-crossed by large dessication cracks. The salt content of the floor is high, supporting a salt-tolerant vegetation.

Gypseous lake floor

West of the Anabranch there are some large, irregular, low-lying areas that have been sites of groundwater evaporation. A preliminary shallow groundwater and salinity map of the Murray Basin (Evans 1988) shows these. For example, the Huntingfield groundwater discharge basins north of Lake Victoria total 443 km^2 and comprise highly saline, gypseous and calcareous clays, with lunettes of cemented siliceous sands (Eldridge 1985). However, not all gypseous lake floor areas have well-defined lunettes and they are usually in regions remote from drainage lines. Large areas of active groundwater discharge are termed boinkas (Macumber 1980).

Alluvium

Near the junction of the Darling and Murray Rivers there are high level alluvial terraces that post-date the linear dunefields. The laminated deposits are dominantly fluviatile and are of mixed ages. Lower level alluvium comprises the modern floodplain and follows the major drainage channels throughout the region. West (downstream) of Wentworth the Lower Alluvium forms a flat alluvial plain below the level of the older Upper Alluvium (Figure 2).

Clay plain and clay plain with sand cover

These features occur east of the dunefields in the large areas between major drainage lines such as between the Darling and the Great Anabranch.

Soils

The Ana Branch – Mildura region is part of the Murray–Darling Plains (VII) of Butler, Blackburn & Hubble (1983). More specifically it is part of their Soil Landscape Province 3, the Murravian Gulfland. Butler (1980) presents a detailed account of the soils of the Mildura region. The aeolian soils of south-western New South Wales has been described by the Soil Conservation Service of NSW (Eldridge 1985). A series of 1:250 000 soils maps is incorporated with detailed notes on the 32 soil-landform associations identified. Figure 4 is based on the Ana Branch and Mildura maps from Eldridge (1985). The figure is considerably simplified but shows the distribution of the eight main soil groups.

The **calcareous sands** (Unit 1, Figure 4), on longitudinal dunefield are restricted to the north-western corner of the linear dunes unit of Figure 3, and to an area west of Lake Victoria. The other soil units associated with the linear dunes are Unit 6 (brown calcareous earths), Unit 7 (grey-brown calcareous earths) and Unit 8 (brown sands/ calcareous earths). Units 6 and 7 are found mainly west and east of the Anabranch of the Darling, but not east of the Darling. Unit 8 is found principally east of the Darling and not west of the Anabranch. The siliceous sands (Unit 2) on sub-parabolic dunes correspond to the irregular sub-parabolic dunes in the far east of the map.

The **saline and gypseous clays** (Unit 4) are found on the gypseous lake floor areas principally west of the Anabranch.

The **red duplex soil** (Unit 5) partly corresponds to the sand plain of Bowler & Magee (1978, Figure 3), and is associated with the Anabranch lakes and with the confluence of the rivers. The river course itself, principally the low level alluvium of Figure 3, is shown here as Unit 3, the grey cracking clays. This unit follows the rivers and includes the lake beds.

All the soils are coarse-textured and prone to wind erosion when the vegetative cover is removed. Where the soils are irrigated there is a problem with salinization as deeper saline waters are drawn to the surface. There are associated changes in floristic composition with the spread of weeds, the loss of useful native perennial species and the increase in some unproductive native shrubs. With cropping there are changes in soil structure and loss of soil nutrients. All of these changes associated with cultivation are addressed in Lievers & Luke 1980, Eldridge & Semple 1982, Stanley 1982, and Walker 1982.

Land systems

The land systems of western New South Wales have been mapped by the Soil Conservation Service of New South Wales. Descriptions of land systems typically comprise combinations of landform, soil and vegetation. Lawrie & Stanley (1980) present an overview of the land system mapping program and describe the eight land systems representative of the mallee lands. The Ana Branch land system map (Eldridge 1985) shows four geomorphological classes: sandplains, dunefields, alluvial plains and playas or basins with respectively 10, 7, 5 and 7 units.

Climate

The climate of the Murray Darling Region has been summarised in the Bureau of Meteorology's Climatological Survey: Region 19 (1955). This summarises information on temperature, evaporation, rainfall and sunshine for the mapped area and to east of the Lachlan River. The region is also covered in a publication on rainfall with special reference to soil conservation (Edwards 1979).

The mapped area falls within the semi-arid region of south-eastern Australia. Rainfall is highest in the south-east (long-term average rainfall Mildura 295 mm, Wentworth

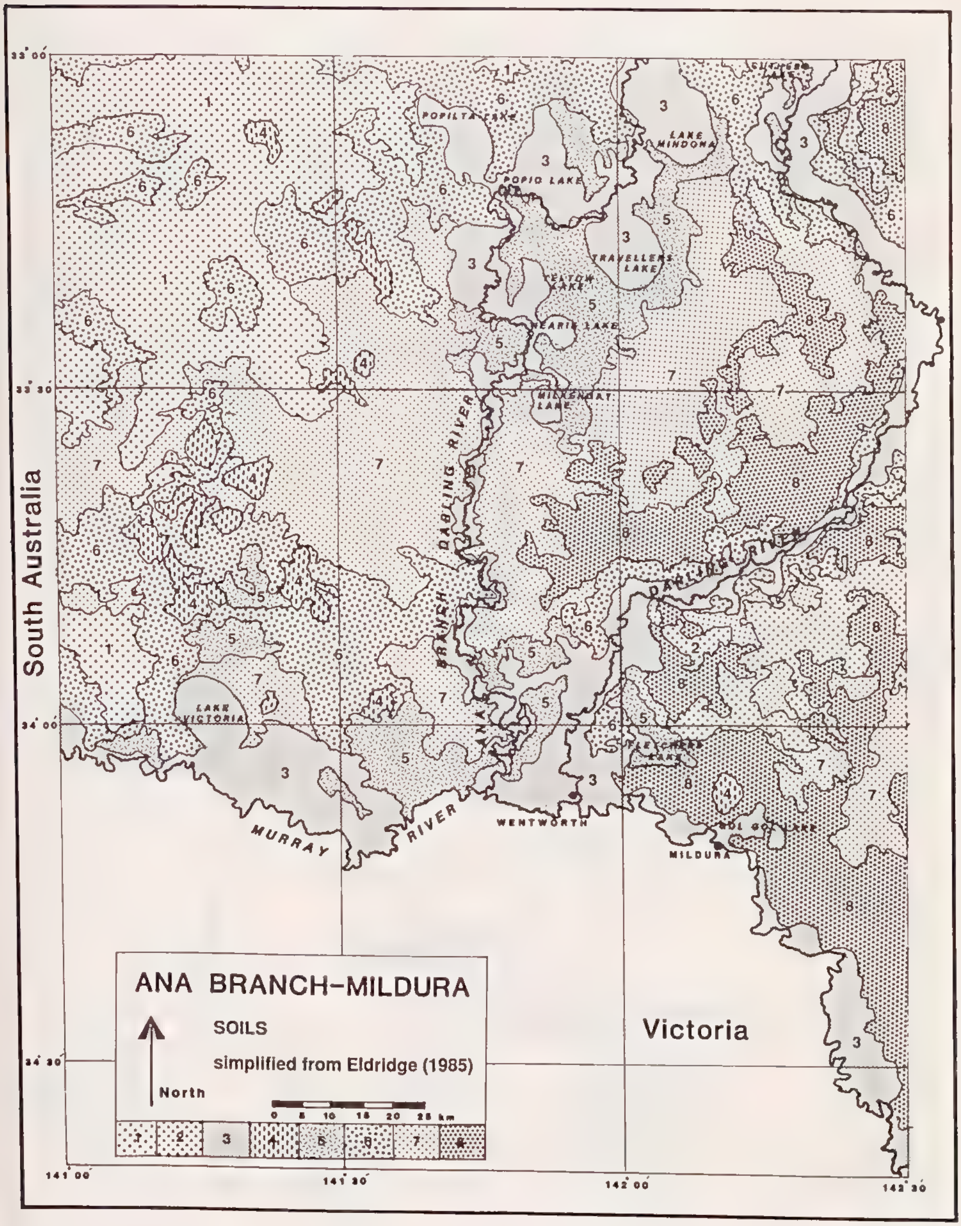


Figure 4. The soils of the mapped area based on maps in Eldridge (1985). **1.** Calcareous sand, dunefield. **2.** Siliceous sand, sub-parabolic dunes. **3.** Grey cracking clays. **4.** Saline and gypseous clays. **5.** Red duplex soil. **6.** Brown calcareous earths. **7.** Grey-brown calcareous earths. **8.** Brown sand/calcareous earths on aligned dunes.

289 mm) and diminishes gradually to the north (Cuthero 247 mm, Broken Hill 249 mm and Menindee 237 mm). Figure 5 shows the long-term (all available records) pattern of rainfall distribution for seven stations on or close to the mapped area. Whereas they all have long-term averages of 200–300 mm, they have received a variable annual amount of rain from less than 100 mm to more than 450 mm, in exceptional years with over 700 mm. This variability in annual rainfall is illustrated in Figure 6 for two of these stations. The long-term average is shown as a dashed line

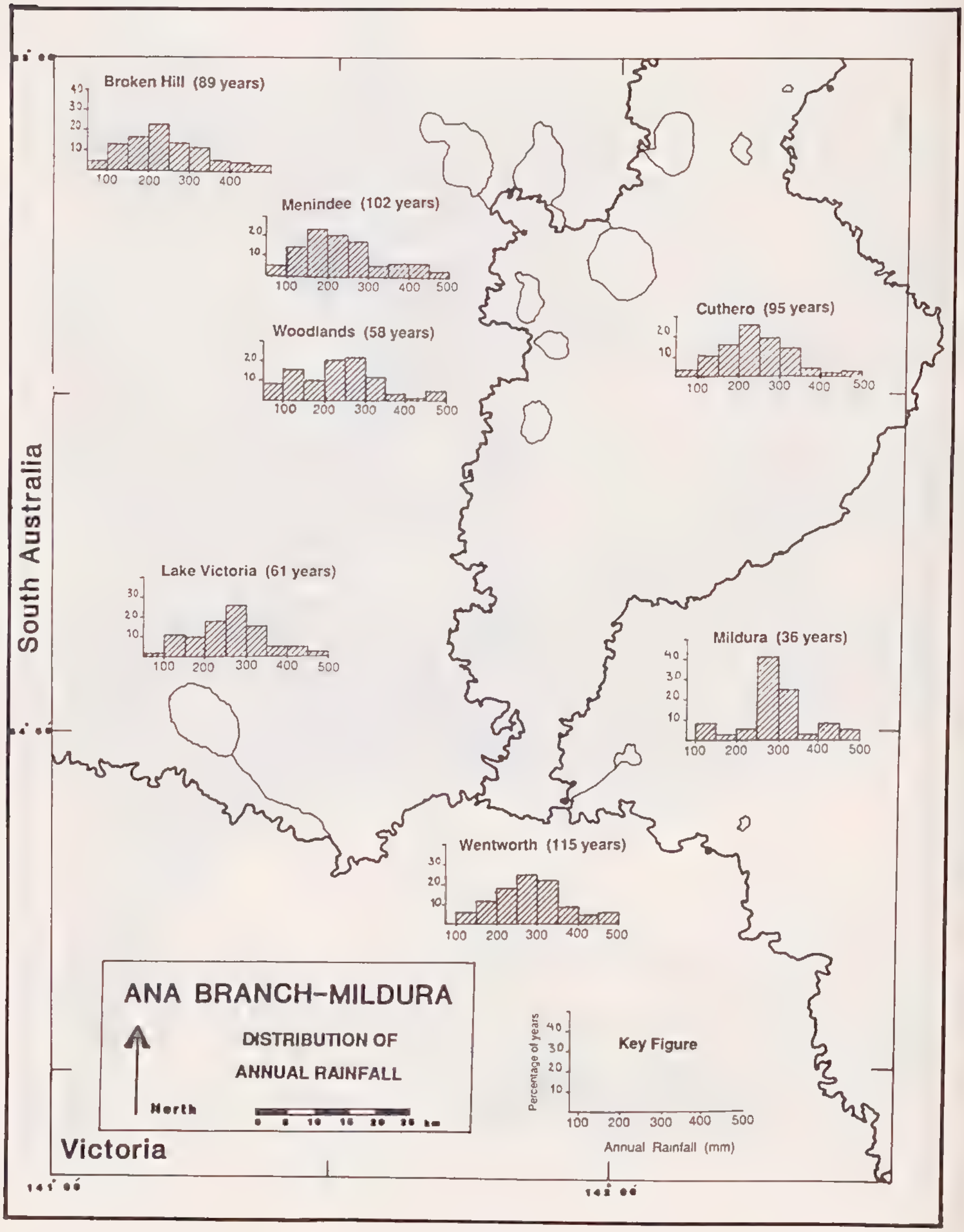


Figure 5. The long-term distribution of rainfall for seven stations on or close to the mapped area (all available data from Bureau of Meterology).

and the yearly values are illustrated. Years of high rainfall such as 1974 are exceptional and may be twice or three times the average annual value.

Figure 7 illustrates the climatograms for five stations on or near the map sheet. Climatograms are designed to show the seasonal fluctuation in water availability (e.g. Walter & Lieth 1967). The average temperature is plotted on the left hand axis and the monthly rainfall on the right hand axis. The stippled portions of the figure

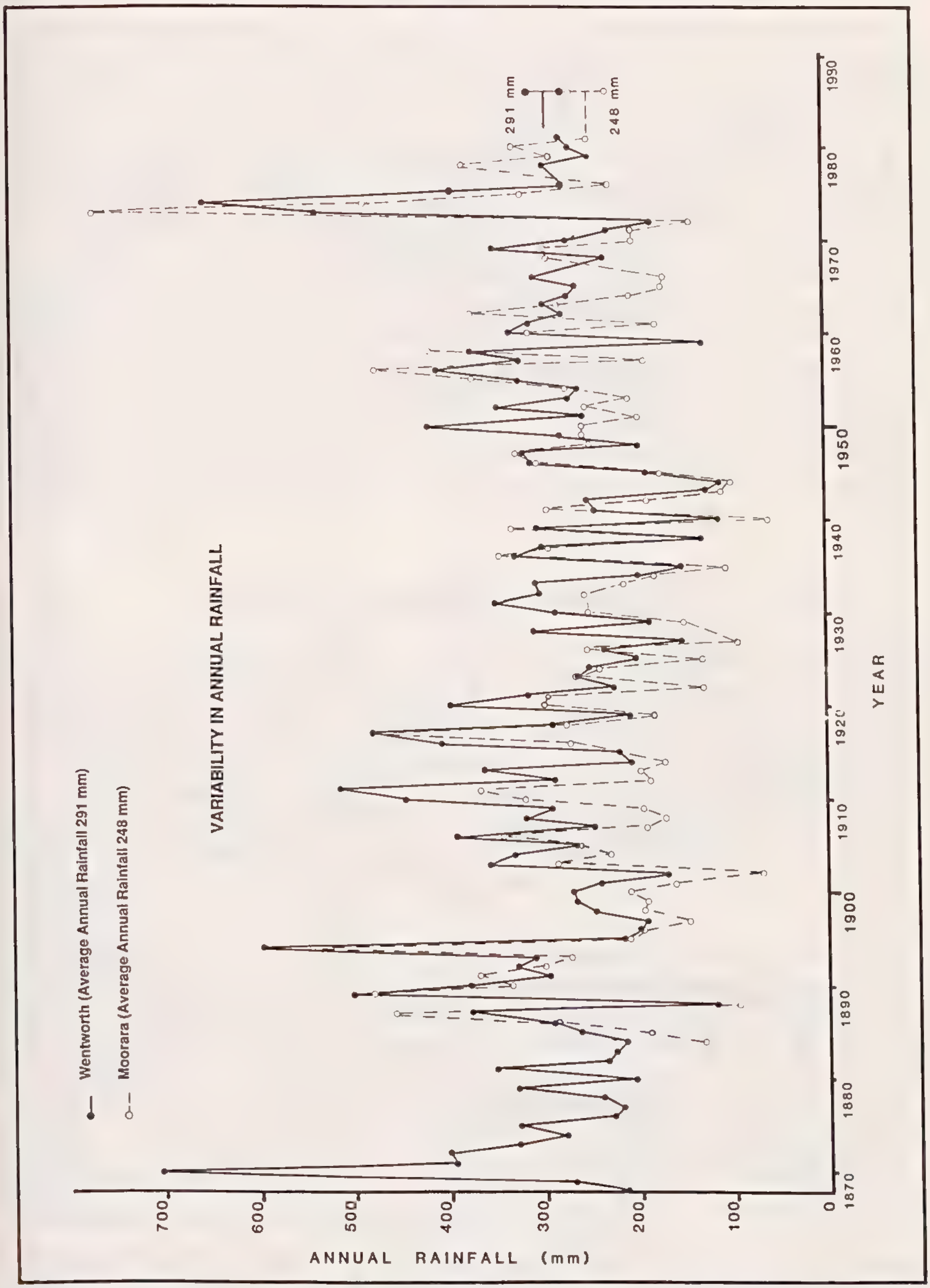


Figure 6. Long-term rainfall record for two stations on the mapped area illustrate the high year-to-year variability.

represent the time of high temperature (and therefore high evaporation) and low rainfall when vegetation would experience moisture deficits. The vertical hatched portion is the winter period when rainfall (especially in the south) is adequate and temperatures are low. All stations may receive rainfall in any month but there is a winter influence in the south which becomes stronger towards Adelaide in the true 'Mediterranean' climatic regions of southern Australia.

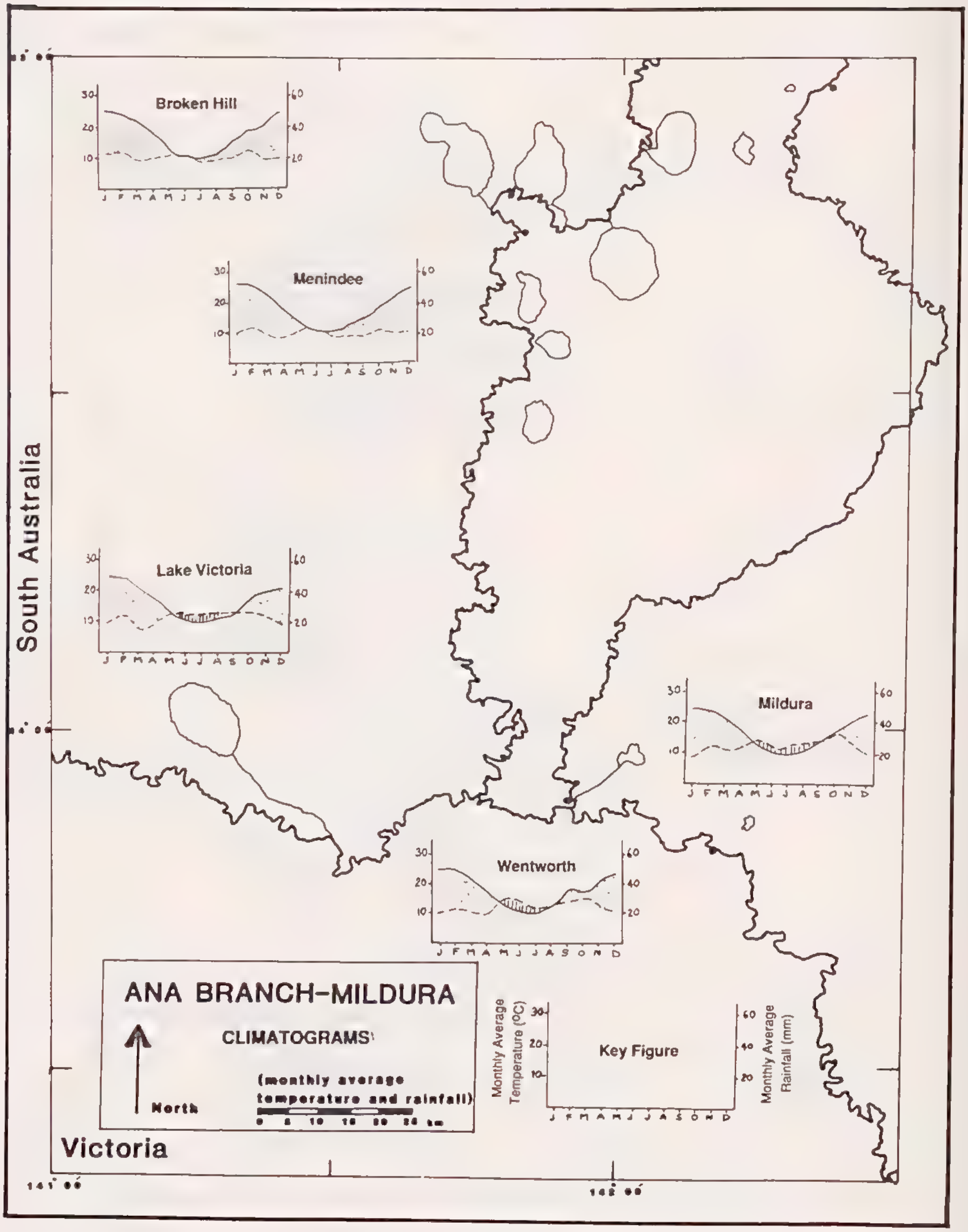


Figure 7. Climatograms for five of the weather stations on or near the mapped area. The figures plot monthly average temperature and rainfall and demonstrate the relatively wet winters in the south of the mapped area.

The region experiences high summer temperatures and high incident radiation, resulting in high evaporation. Winter temperatures do go below freezing point at night and frosts may occur on 10% of winter nights. Effective rainfall occurs in the winter months but absolute amount and distribution varies from year to year.

Vegetation

The natural vegetation of the mapped area has received some treatment in the scientific literature. Cambage (1914) presented an early treatment of the flora of the west Darling country. Beadle (1948) prepared a comprehensive account of the whole of the Western Division which includes this mapped area. He also produced the only published vegetation map of the Western Division (Beadle 1945). A section of his map is reproduced in Figure 8. Two principal vegetation types predominate, and both are associated with the linear dunefield and sub-parabolic dunes. These are mallee (Unit 1, Figure 8) and *Casuarina* woodland (Unit 2). Along the river alluvium is the third unit, a *Eucalyptus* woodland. Shrublands dominated by members of the Chenopodiaceae occur on the sandplain and high level alluvium (Figure 3). These comprise one association of species of *Maireana* (Unit 4) and one of *Atriplex vesicaria* (Unit 5). This is an over-simplification of the range of vegetation types present but serves to illustrate the basic simplicity of the system. Just as there are relatively few geomorphological units, there are relatively few vegetation types. The vegetation comprises structurally simple, low woodlands or shrublands; the only tall forest vegetation is a narrow band of riverine *Eucalyptus* forest along the rivers and associated channels.

Aboriginal history

Four tribal groups occupied country covered by the Ana Branch – Mildura map. These were the Wilyali from the far northwest of the area, the Bolali from west of the Anabranch, and further south, the Yu-Yu from near Lake Victoria. To the north of Pooncarie were the Bagundji (Moore 1979). The Bagundji's territory extended along much of the course of the Darling river and to the west of it (Allen 1979). Allen lists the following tribes as belonging to this tribal group: Bagundji, Barindji, Danggali, Bolali, Wilyagali, Bandjigali, Wanywalgu and Baruṅdji. (Some of these are alternative spellings for the tribes listed by Moore 1979.) These all belonged to the Wiradhuri nation (Moore 1979). This group of tribes occupied the basins of the Murray, Murrumbidgee and Lachlan rivers.

The Darling River region supported a large Aboriginal population. The river and plains offered abundant resources and Aboriginal groups were larger and less nomadic than those in higher rainfall areas further east (Allen 1979). Aboriginal use of native plants is only partially known, but the use of the rhizomes of *Typha* spp. is well documented, as is the harvesting and preparation of seed from Native Millet, *Panicum decompositum* (Allen 1979). Seeds of Pigweed, *Portulaca* sp., and the sporocarps of Nardoo, *Marsilea drummondii*, were also used. During winter the seeds of Saltbush (*Atriplex* spp.), Wattles (*Acacia* spp.) and Flax plants (*Linum marginale*) were eaten (Cribb & Cribb 1974). Allen (1979) lists 24 plants eaten by the Aborigines of the Darling Basin.

The main evidence of pre-European Aboriginal activities are the 'canoe' trees, usually River Red Gum, *Eucalyptus camaldulensis*, but also Black Box, *E. largiflorens*. These trees are scarred by the removal of large ovals of bark and sapwood for the manufacture of small canoes and coolamons for carrying babies or food. Since there are no rock outcrops in the mapped area there are few rock-associated artefacts, although imported stone tools have been found.

Creamer (1979) maps two massacre sites close to and just east of Lake Victoria. Burial mounds may have occurred but have been obliterated over time. Oxley excavated several mounds near the Lachlan River in 1820. These were sometimes surrounded by decorated trees.

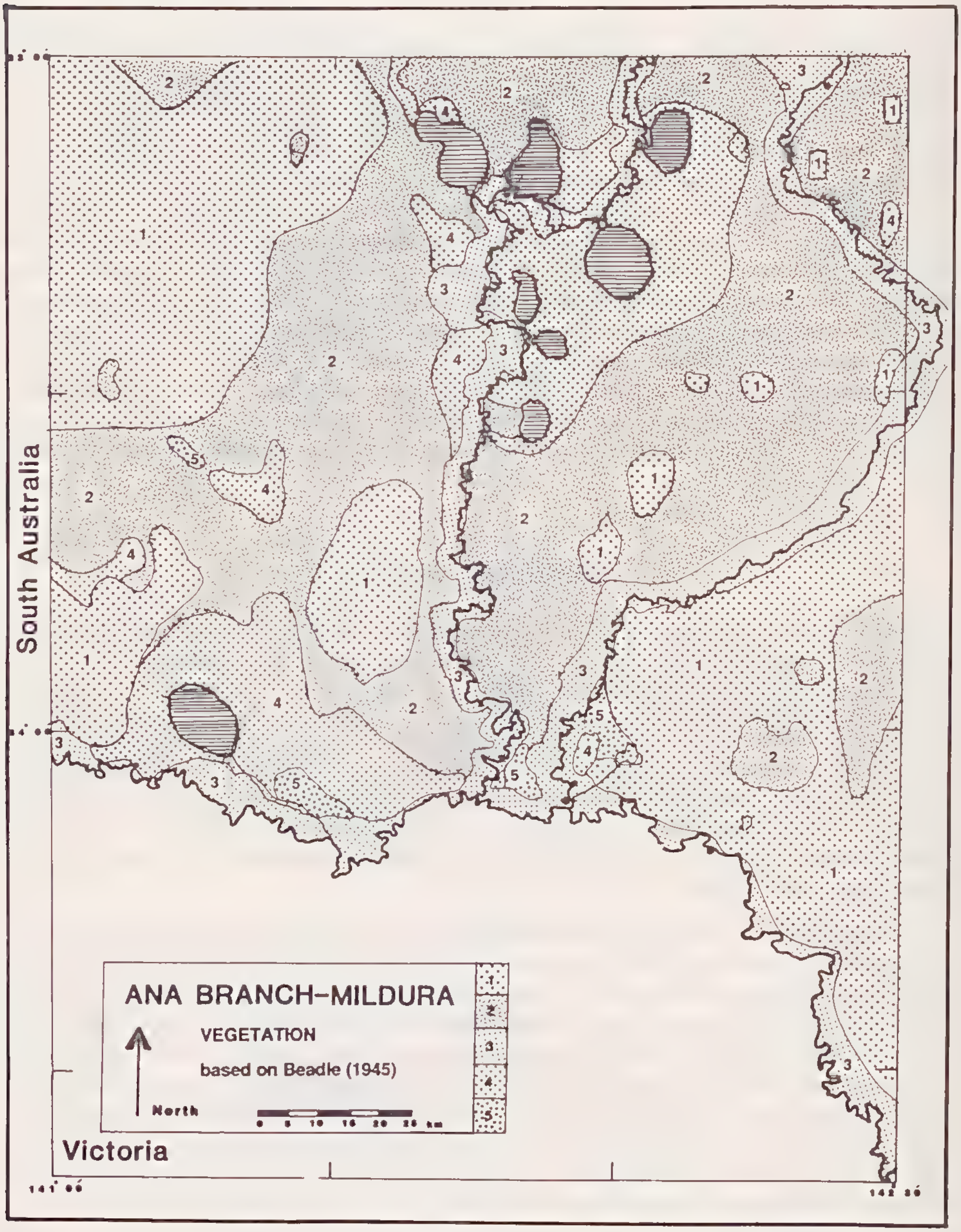


Figure 8. The vegetation of the mapped area based on a map by Beadle (1945). **1.** *Eucalyptus socialis – E. dumosa* association. **2.** *Casuarina–Alectryon* association. **3.** *E. largiflorens* association. **4.** *Maireana pyramidata – M. sedifolia* association. **5.** *Atriplex vesicaria* association.

Within the mapped area there is a very significant archaeological site in the lunette of Lake Victoria (Marshall 1973). Two other sites are located just north of the mapped area in the lunette of Lake Tandou and Lake Menindee. Here fossils of extinct Pleistocene animals such as *Diprotodon*, *Protemnodon*, *Sthenurus* and *Procoptodon* have been found (Merrilees 1973). To the east are the famous sites associated with the Willandra lakes. The best-dated faunal material from the late Pleistocene of semi-arid Australia has been derived from lunettes in western New South Wales (Hope 1982).

European settlement

The history of European occupation of the Far Western Plains of New South Wales began with the exploration along the river courses by British explorers. Captain Charles Sturt explored along the length of the Murray River in 1828 and 1830. Sturt reached the Darling in 1829 and named it in honour of Governor Ralph Darling, although the river had been crossed in its upper reaches by Allan Cunningham in 1827. Major Thomas Mitchell explored the northern half of the Darling in 1835 and later confirmed Sturt's assertion that it joined the Murray.

Pastoral settlement spread slowly west from Sydney and northwards from the more fertile areas of Victoria. The whole of the mapped area falls within the 1858 Police District of Balranald (Robinson 1976) which was subdivided by 1865 to a number of smaller districts of which Wentworth covers most of the mapped area. An indication of the rate of settlement comes from the wheat harvests for each Police District. The figures for Balranald are nil (1861), 7 acres (1866), 14 acres (1871), nil (1876) and 385 acres (1879). No acreage is given for Wentworth during this period. The land had largely been settled by 1860 and the principal pursuit was, and still is, running sheep. In the 1870s seasonal conditions were good and there was a rapid increase in sheep numbers. By 1877–1891 stock numbers had increased to two to three times those of today. A prolonged drought that ended in 1902 saw numbers crash to half of present levels. A Royal Commission was held into the western leasehold pastoral lands in 1901. It found that the low rainfall, extensive rabbit infestation, overstocking and subsequent erosion combined with high rentals, low wool prices, property depreciation and financing difficulties were all factors contributing to the plight of Crown Tenants in the Western Division. The Western Lands Act of 1901 arose from the recommendations of the Commission. An overview of the history of pastoralism is given in Condon (1983).

In an area with low and unpredictable rainfall the land away from the rivers could only be used in periods of good rain until the introduction of well sinking and tank formation in the late 1860s. Until the introduction of windmills, water was pumped by people or horsepower (Condon 1976). Quite early in the history of settlement there were ambitious schemes to irrigate the land away from the rivers and the Chaffey brothers introduced irrigation schemes at Mildura and Renmark in the 1880s.

Previous vegetation surveys

There have been a number of previous vegetation surveys covering part or whole of the mapped area beginning with Cambage (1914). In 1923 Albert Morris, famed for his revegetation of the environs of Broken Hill, published an account of the flora between the Darling River and Broken Hill (Morris 1923); this relates mainly to the vegetation to the north of the map sheet but is relevant to the region. Also in 1923, Marjorie Collins published the first of a series of papers on the vegetation of arid and semi-arid New South Wales (Collins 1923). Again this paper, on the vegetation of the Barrier District, deals with a region largely north of that treated here.

The most comprehensive treatise on the vegetation of western New South Wales is 'The Vegetation and Pastures of Western New South Wales' (Beadle 1948) with an accompanying coloured vegetation map at a scale of 1" = 16 miles (c. 1:1 000 000)(Beadle 1945). More recently, Beadle (1981) includes chapters that describe the vegetation communities of the west in his book on the vegetation of Australia. Other general accounts of major vegetation types are chapters by Johnson & Burrows (Acacia communities), Parsons (mallee) and Leigh (chenopod shrublands), in Groves (1981). Noble & Mulham (1980) summarise the features of the mallee communities. A more quantitative account of the vegetation of the semi-arid region of south-eastern Australia was published by Noy-Meir (1971) and an unpublished vegetation map (1:1 000 000) was produced by the same author in the course of his work (Noy-Meir 1981).

To the east of the map sheet lies Mallee Cliffs National Park and a recent publication has mapped its vegetation and described the communities (Morcom & Westbrook 1990). Further south of the mapped area, in north-western Victoria, Connor (1966) reported on the vegetation of the Beulah–Hopetoun area in a series on the vegetation of the north-west of Victoria. Also in northwestern Victoria, Gullan (1991) describes the practicalities of floristic mapping in the Victorian mallee, the region due south of the Ana Branch – Mildura map.

The flora of the region

Several published species lists cover the map area. Semple (1985) lists the vascular plants of the mallee communities of south-western New South Wales. Semple (1986) lists the vascular plant species for the riverine plain, many of which occur on the alluvial landforms of the mapped area.

The book 'Plants of Western New South Wales' (Cunningham, Mulham, Milthorpe & Leigh 1981) includes an account of the vegetation of the region as well as photographs and notes on the flora of the area. The book describes 2027 species of vascular plants, including 19 species of ferns. These species represent 635 genera from 129 families. The most abundant families are the Poaceae (297 species), Asteraceae (265 species), Chenopodiaceae (146 species), Faboideae (137 species) and Mimosoideae (80 species). The authors also describe 407 species which are established in natural communities but are not native to Australia. This compilation is for the whole of the Western Division which cover four botanical subdivisions (see map at back of issue), viz the North Western Plains (NWP), South Western Plains (SWP), North Far Western Plains (NFWP) and South Far Western Plains (SFWP). The Ana Branch – Mildura map sheet falls within the last of these. Table 1 lists the total number of species in six broad categories for the four botanical subdivisions.

There are a number of interesting features in the tallies shown in Table 1. In each division the northern subdivision is richer in all groups than is its southern counterpart, except for conifers, which are richer in the south. The other gross pattern is the greater richness of the Western Plains compared with the more arid Far Western Plains. There are also proportionally more monocotyledons to dicotyledons in the Western Plains subdivisions (0.33 N and 0.30 S) than in the Far Western Plains (0.22 N and 0.16 S). This is largely influenced by the grasses of which there are 215 species in the Western Plains and only 121 in the Far Western Plains.

Some families are better represented in the Far Western Plains. For instance the chenopods (Chenopodiaceae) number 104 species in the Western Plains and 134 species in the Far Western Plains. Other families such as the Fabaceae or other groups such as Mimosoideae (Fabaceae) have over twice as many species on the Western Plains (84 species) as on the Far Western Plains (37 species). Some families are almost

Table 1. The number of plant species in broad taxonomic categories for the four Botanical Subdivisions in western New South Wales (numbers based on Jacobs & Pickard 1981, ferns from Cunningham et al. 1981).

Plant group	**Botanical sub-division**				**Total all Western Plains**
	NFWP	**SFWP**	**NWP**	**SWP**	
Cycads	0	0	1	0	1
Conifers	2	3	3	4	4
Monocotyledons	154	80	306	217	405
Dicotyledons	710	512	936	727	1370
Exotic monocots	37	(37)	108	(108)	117
Exotic dicots	134	(134)	284	(284)	310
Total native species (excluding ferns)	866	595	1246	948	1775
Total exotic spp.					427
Total ferns (Cunningham et al. 1981)					19
Total vascular plant species					**2226**

equally abundant in the two divisions, especially when the larger area of the Western Plains is taken into account. The Asteraceae are represented by 182 species in the Western Plains and 150 species in the Far Western Plains. The subdivision in which the map sheet falls has a total of 595 species recorded in Jacobs & Pickard (1981).

Structural vegetation types

Vegetation types are described by structural attributes, principally height of the tallest stratum and percent foliage cover (Specht 1981). The floristic associations are then used to further distinguish the vegetation unit. Table 2 lists the structural formations and floristic alliances represented in south-western New South Wales (from Specht et al. 1974). The height range and foliage cover range for each alliance are given.

Methods

Vegetation mapping

Initial air photo interpretation employed composite photomosaics (1:50 000) based on 1964–65 aerial photos (NSW Department of Lands). Different photopatterns were recognised and marked directly on the mosaics. These were then traced onto film and reduced to the provisional mapping scale of 1:100 000. These boundaries were transferred to topographic maps at the same scale. These topographic maps are particularly useful, showing most station tracks and locations of dams and bores accurately. By comparison with the only published vegetation map of the region (Beadle 1945) tentative names were assigned to the photopatterns and then confirmed or reassigned after field inspection. Because of the scale of vegetation patterns in the mapped region and the flatness of the terrain, it was considered inappropriate to use stereoscopic pairs of air photographs.

Table 2. Structural formations and floristic alliances represented in south-western New South Wales (from Specht et al. 1974). The height range (m) and foliage cover range (%) for each alliance are given.

Structural formation	Floristic alliance	Height. (m)	Cover (%)
Open-forest			
Swamp sclerophyll forest	*Eucalyptus camaldulensis*	10–30	30–70
Woodland			
Savannah woodland	*Eucalyptus largiflorens*	10–30	10–30
Low open-forest			
Mallee	*Eucalyptus socialis – E. dumosa*	5–10	30–70
Low woodland			
Fringing woodland	*Eucalyptus camaldulensis*	5–10	10–30
Fringing woodland	*E. largiflorens*	5–10	10–30
Low open woodland			
Fringing woodland	*Eucalyptus largiflorens*	5–10	<10
Closed shrub			
Lignum swamp	*Muehlenbeckia cunninghamii*	2–8	70–100
Open shrub			
Mallee	*Eucalyptus socialis – E. dumosa*	2–8	30–70
Arid shrubland	*Casuarina pauper – Alectryon oleifolius*	2–8	30–70
Tall shrubland			
Mallee	*Eucalyptus socialis – E. dumosa*	2–8	10–30
Arid shrubland	*Casuarina pauper – Alectryon oleifolius*	2–8	10–30
Open heath			
Saltbush	*Atriplex vesicaria*	0–2	30–70
	Maireana spp.	0–2	30–70
	Chenopodium nitrariaceum – Eremophila maculata	0–2	30–70
	Atriplex inflata	0–2	30–70
Low shrubland			
Saltbush	*Atriplex vesicaria*	0–2	10–30
	Maireana spp	0–2	10–30
	Chenopodium nitrariaceum – Eremophila maculata	0–2	10–30
	Atriplex inflata	0–2	10–30
Saltpan	*Sclerostegia tenuis – Minuria cunninghamia*	0–2	10–30
Low open-shrubland			
Saltbush	*Atriplex vesicaria*	0–2	<10
	Maireana spp.	0–2	<10
Herbfield/grassland			
Canegrass swamp	*Eragrostis australasica*	0–2	30–70
Sedgeland			
Swamp	*Azolla sp.*	0–2	30–70
Saltpan	*Sclerostegia tenuis*	0–2	30–70
Arid herbfield	Ephemerals	0–2	30–70
Open sedgeland			
Saltpan	*Sclerostegia tenuis*	0–2	10–30

Survey techniques

Field surveys were conducted over a period from late 1979 to 1989 in a variety of seasons. Figure 9 shows the principal field traverses along roads and station tracks. As well as these, excursions were made on foot to areas that were difficult to reach by vehicle.

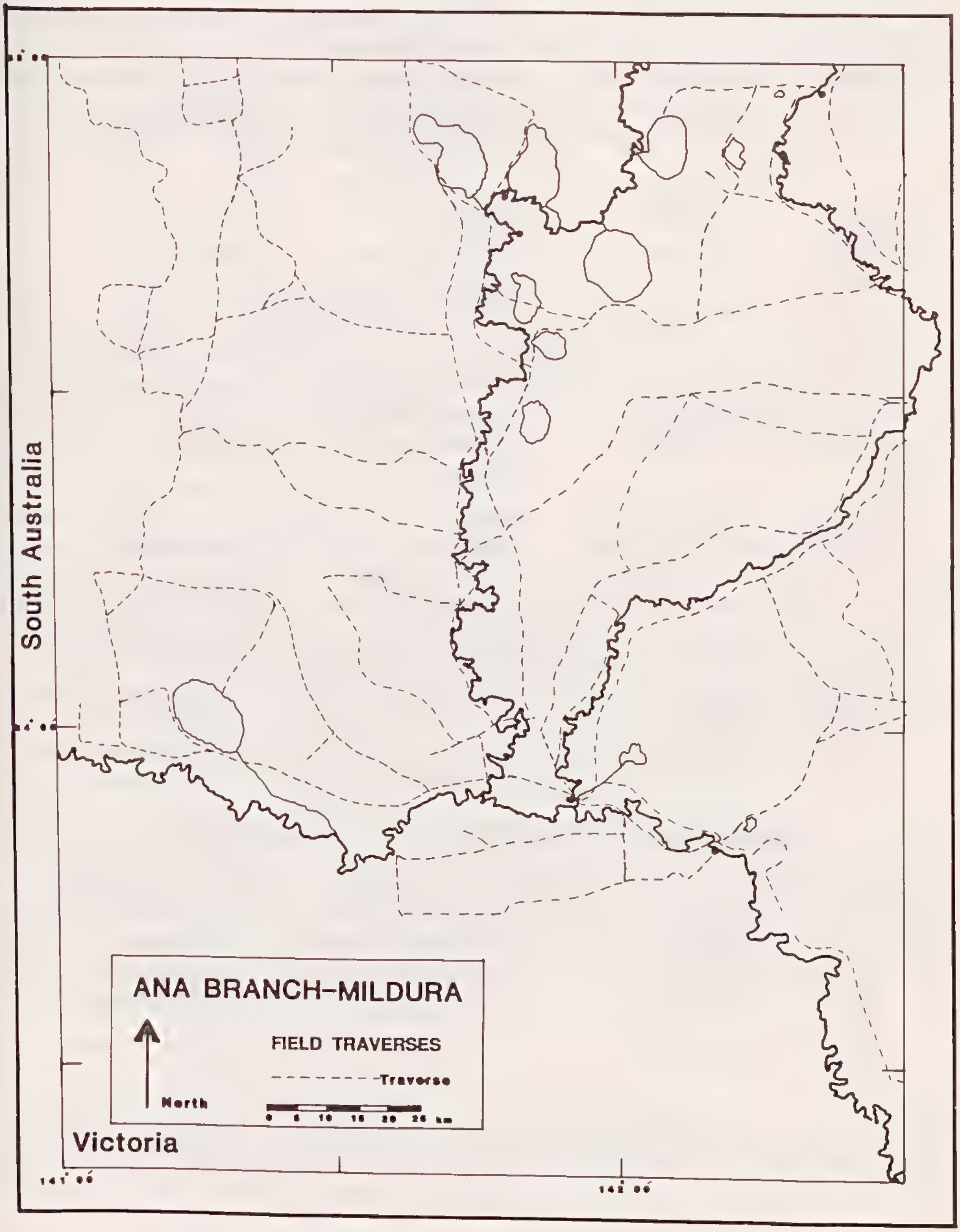


Figure 9. Location of major field traverses completed in the vegetation survey of the mapped area.

Table 3. Map unit descriptions

No.	Code	Structure	Main species	Dominant plant community
1	eM3F	Open-forest	*Eucalyptus camaldulensis*	Riverine Forest
2	eM2S	Low open woodland	*Eucalyptus largiflorens* *Atriplex nummularia*	Black Box Woodland
3	eS2H	Tall shrubland	*Eucalyptus socialis* *E. dumosa*	Dune Mallee
4	cS2Z	Tall shrubland	*Casuarina pauper* *Alectryon oleifolius* subsp. *canescens*	Arid Shrubland
5	eS2H/ cS2Z	Tall shrubland	Mosaic of 3 with 4	Arid Shrubland
6	cS2Z/ eS2H	Tall shrubland	Mosaic of 4 with 3	Arid Shrubland
7	cS2Z/ eS2H/ kZ2F	Tall shrubland	Mosaic of 4, 3 & 8	Arid Shrubland
8	kZ2F	Low shrubland	*Maireana pyramidata* *Rhagodia spinescens*	Black Bluebush
9	kZ2F	Low shrubland	*Maireana sedifolia* *Erodium* spp.	Bluebush
10	kZ2F	Low shrubland	*Maireana pyramidata* *Atriplex* spp.	Lunette Shrubland
11	kZ1F	Low open-shrubland	*Atriplex vesicaria* *Sclerostegia tenuis*	Bladder Saltbush
12	kZ1F	Low open-shrubland	*Sclerostegia tenuis* *Atriplex* spp.	Pigface-Samphire
13	yG3F	Grassland	*Eragrostis australasica*	Canegrass Swamp
14	gG3F	Sedgeland	*Eleocharis pallens*	Sedge Swamp
15	kF2F	Open herbland	*Disphyma clavellatum* *Sclerostegia tenuis*	Saltpan, Lakebed

Plant communities too small to be shown as separate map units

Code	Structure	Main species	Dominant plant community
eS2H	Tall shrubland	*Eucalyptus oleosa*	Sand Plain Mallee
eS2H	Tall shrubland	*Eucalyptus gracilis*	Swale Mallee
pM2S	Open woodland	*Callitris glaucophylla*	Mixed Woodland
wS3F	Tall shrubland	*Acacia victoriae*	Acacia Shrubland
xS4F	Closed shrubland	*Muehlenbeckia cunninghamii*	Lignum Swamp
kS3F	Tall shrubland	*Atriplex nummularia*	Old Man Saltbush

Map units show original vegetation cover before European settlement, as interpreted from aerial photography and field survey. Present vegetation has been affected by widespread grazing and localised clearing.

After the initial mapping stages, provisional maps (at 1:100 000) were taken into the field and checked. Sites were established in all the map units so as to characterise the vegetation. A set of permanent sites was established in the drought year of 1982 across south-western NSW, some of these were in Kinchega National Park just north of the mapped area. Sites usually comprised a rectangular quadrat 100 m long by 40 m (0.4 ha). This was searched methodically and all identifiable vascular plant species recorded. Specimens were taken for verification and these are lodged in the National Herbarium of NSW. The structure of the vegetation was recorded as the height of the different strata and their respective projected foliage cover. Notes were made on the condition of the vegetation, the soil type, any evidence of fire, grazing, weed infestations, erosion. At a subset of sample points, soil samples were collected from the top 40 cm and analysed by the NSW Department of Agriculture's chemistry laboratory for exchangeable cations, pH and electrical conductivity.

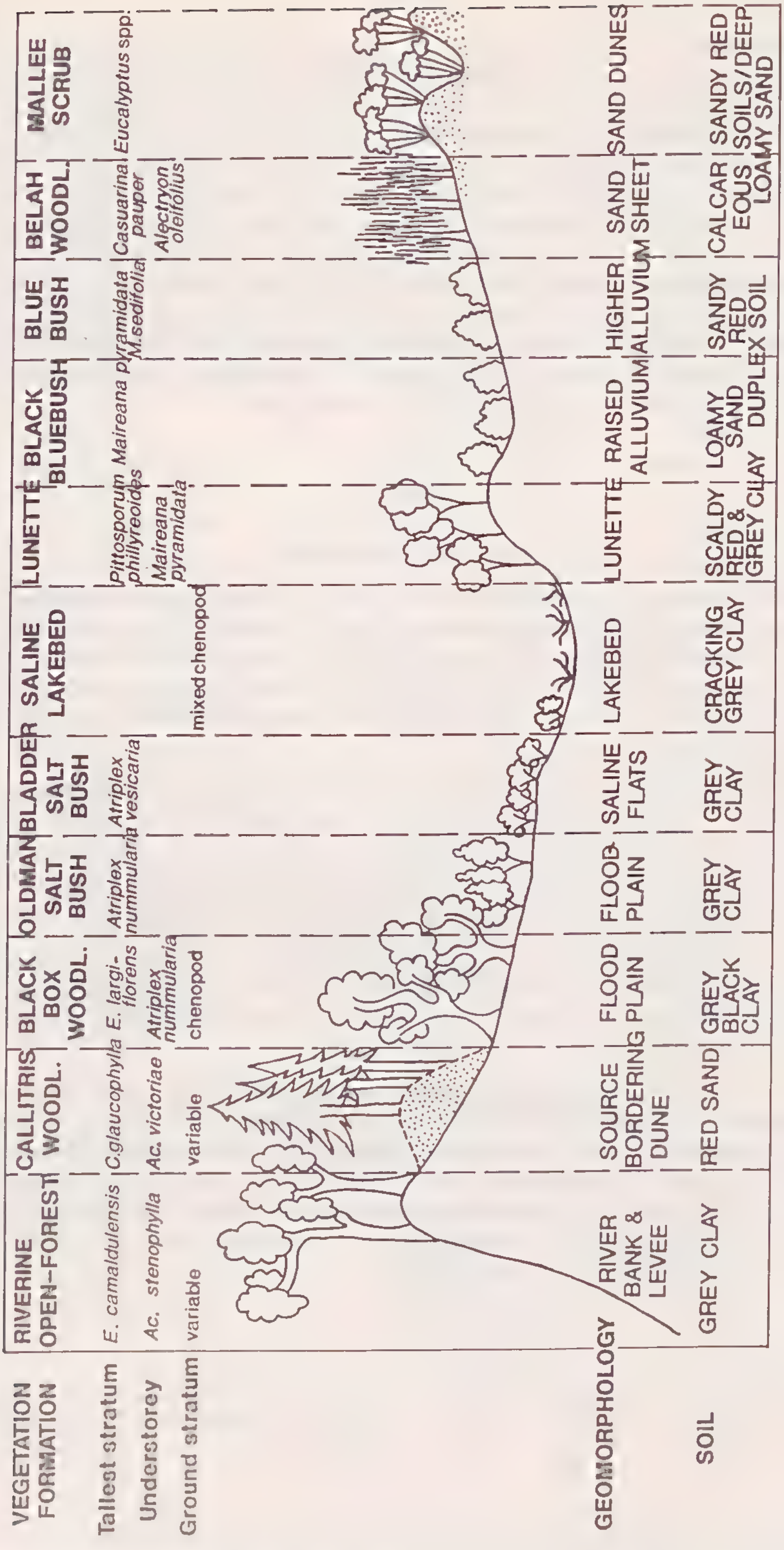
Results

The vegetation types

The principal structural formation is the shrubland, either low open-shrublands dominated by members of the Chenopodiaceae, or tall shrublands dominated by mallee eucalypts and *Casuarina pauper*. The only tall forests are the River Red Gum forests fringing the rivers. Elsewhere on the periodically flooded flats are extensive woodlands of *Eucalyptus largiflorens*. Table 3 provides a concise description of the fifteen units mapped.

The distribution of these map units is shown on the vegetation map (back pocket). The map shows vegetation as it is assumed to have been before European setlement. Map units do not always correspond with single communities. There are vast areas with mixtures of two or more communities which cannot be separated at this mapping scale. The reason for the amount of intermingling is the nature of the landscape with, for example, shallow sand mantling heavier clay alluvium. In such a case there may be linear patches of mallee on the sand and *Casuarina* woodland in deflated areas where the heavier soil is exposed. There are other plant communities whose occurrences are always too small to map at this scale. They are described in the section on Plant Communities.

Map units are coded by the alphanumeric code used by Carnahan (1989). This is a four-character code, with the first three characters for the tallest stratum and the last one for the lower stratum. For example eS2H signifies that the predominant genus in the tallest stratum is *Eucalyptus* (e), the growth form is tall shrub (S) with 10–30% foliage projective cover (2), and the lower stratum is dominated by hummock grasses (H). In other words, this unit is mallee with *Triodia* understorey. The full key and explanation are given on Carnahan (1989).



VEGETATION FORMATION	Tallest stratum	Understorey	Ground stratum	GEOMORPHOLOGY	SOIL
RIVERINE OPEN-FOREST	*E. camaldulensis*	*Ac. stenophylla*	variable	RIVER BANK & LEVEE	GREY CLAY
CALLITRIS WOODL.	*C.glaucophylla*	*Ac. victoriae*	variable	SOURCE BORDERING DUNE	RED SAND
BLACK BOX WOODL.	*E. largiflorens*	*Atriplex nummularia*	chenopod	FLOOD PLAIN	GREY BLACK CLAY
OLDMAN SALT BUSH	*Atriplex nummularia*			FLOOD PLAIN	GREY CLAY
BLADDER SALT BUSH	*Atriplex vesicaria*			SALINE FLATS	GREY CLAY
SALINE LAKEBED			mixed chenopod	LAKEBED	CRACKING GREY CLAY
LUNETTE	*Pittosporum phillyreoides*	*Maireana pyramidata*		LUNETTE	SCALDY RED & GREY CLAY
BLACK BLUEBUSH	*Maireana pyramidata*			RAISED ALLUVIUM	LOAMY SAND DUPLEX
BLUE BUSH	*M.sedifolia*			HIGHER ALLUVIUM	SANDY RED SOIL
BELAH WOODL.	*Casuarina pauper*	*Alectryon oleifolius*		SAND SHEET	CALCAREOUS
MALLEE SCRUB	*Eucalyptus* spp.			SAND DUNES	SANDY RED SOILS/DEEP LOAMY SAND

Figure 10. Idealised vegetation continuum from river to sand dunes showing relative topographic arrangement of major vegetation types.

The plant communities

Figure 10 is a highly simplified and stylized profile of the landscape to show the relative occurrences of the plant communities.

1. Riverine Forest, River Red Gum Forest

Map units: 1 (2)
Code: eM3F
Structural formation: Open-forest
Height: 25–40 m
Cover: 30–70%
Dominant species: *Eucalyptus camaldulensis* on levees: *E. largiflorens* on flats and along smaller streams.
Understorey species: *Acacia stenophylla, Chenopodium nitrariaceum, Melaleuca lanceolata.*
Ground layer: Mix of herbaceous species, many exotics
Species richness: (0.1 ha) 23.4 ± 4.1 (n=5)
Landform: River levees and flats between braided streams.
Habitat (photopattern): Often concentric linear photopatterns with oxbows
Soil: Heavy grey alluvium
Degradation/regeneration: Subject to frequent and prolonged flooding, major regeneration occurs as floods subside leading to 'wheatfield' regeneration of extremely dense seedling growth which gradually thin out as plants grow. Very fine stands of Riverine Forest occur along the upper reaches of the Anabranch and along the Murray River. Elsewhere they usually form a narrow band following the major streams. (Figure 11).

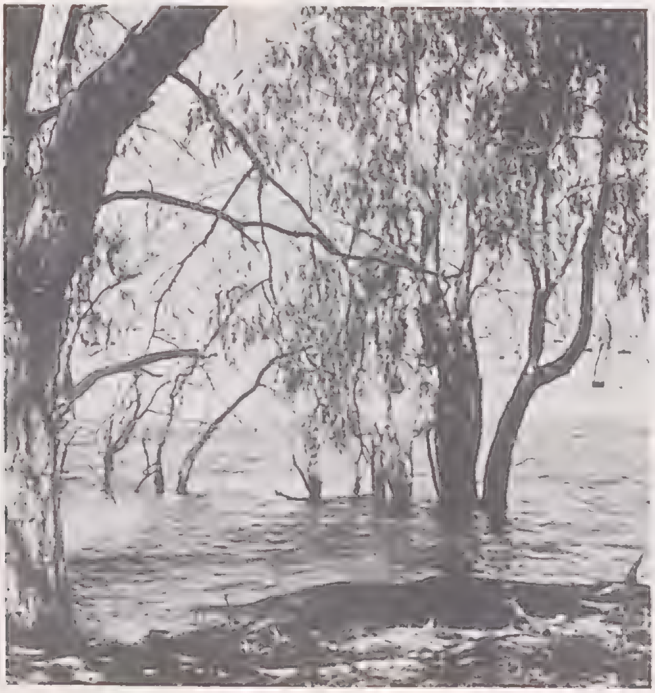


Figure 11. River Red Gum (*E. camaldulensis*) flooded by the Darling River near Pooncarie.

2. Black Box Woodland

Map units: 2 (11, 12, 15)
Code: eM2S
Structural formation: Low open-woodland
Height:10–20 m
Cover: 10–30% (Basal area 0.5 m^{2}ha^{-1})
Dominant species: *Eucalyptus largiflorens*
Understorey species: *Atriplex nummularia, Chenopodium nitrariaceum.*
Ground layer: *Osteocarpum acropterum* var. *deminutum, Boerhavia diffusa, Chamaesyce drummondii, Scleroblitum atriplicinum*
Species richness: (0.1 ha) 36.6 ± 3.0 (n=7)
Landform: Floodplains beyond major rivers and dry lake margins
Habitat (photopattern): Along creek lines and less dense than Riverine Forest
Soil: Heavy grey clay
Degradation/regeneration: Subject to periodic inundation, major regeneration occurs as floods subside. Most stands contain trees of similar size (age) and may represent past establishment patterns. The Black Box Woodlands are prime grazing country and the understorey is affected by this land use. In particular much of the previously extensive *Atriplex nummularia* stands that formed a shrub layer under and between the Black Box trees have now been lost. (Figure 12).

3. Dune Mallee

Map units: 3 (5, 6, 7)
Code: eS2H
Structural formation: Tall shrubland
Height: 2–10 m (function of time since fire)
Cover: 10–30% (Basal area 5m^2 ha^{-1})
Dominant species: *Eucalyptus socialis, E. costata, E. dumosa*
Understorey species: *Triodia irritans, Beyeria opaca, Podolepis capillaris, Chenopodium curvispicatum, Stipa nitida, Enchylaena tomentosa*
Species richness: (0.1 ha) 25.4 ± 0.8 (n= 5)
Landform: Longitudinal east-west dunes up to 10 m in height
Habitat (photopattern): Forms prominent small-grained photopattern
Soil: Calcareous red sand overlying grey clay
Degradation/regeneration: The dunes may become active with a wind-blown sandy surface if highly disturbed. Whereas the mallee eucalypts can resprout from lignotubers, *Triodia* is killed and new plants germinate soon after fire. Seedling eucalypts were rarely noted. Some areas of mallee have been cleared in the past. (Figure 13).

4. Arid Shrubland, Belah-Rosewood

Map units: 4 (5, 6, 7)
Code: cS2Z
Structural formation: Tall shrubland
Height: 8–12 m
Cover:10–30% (Basal area 2.5 m^{2}ha^{-1})
Dominant species: *Casuarina pauper, Alectryon oleifolius* subsp. *canescens.*
Understorey species: *Maireana pyramidata, Olearia pimeleoides, Enchylaena tomentosa, Sclerolaena* spp., *Aristida contorta.*

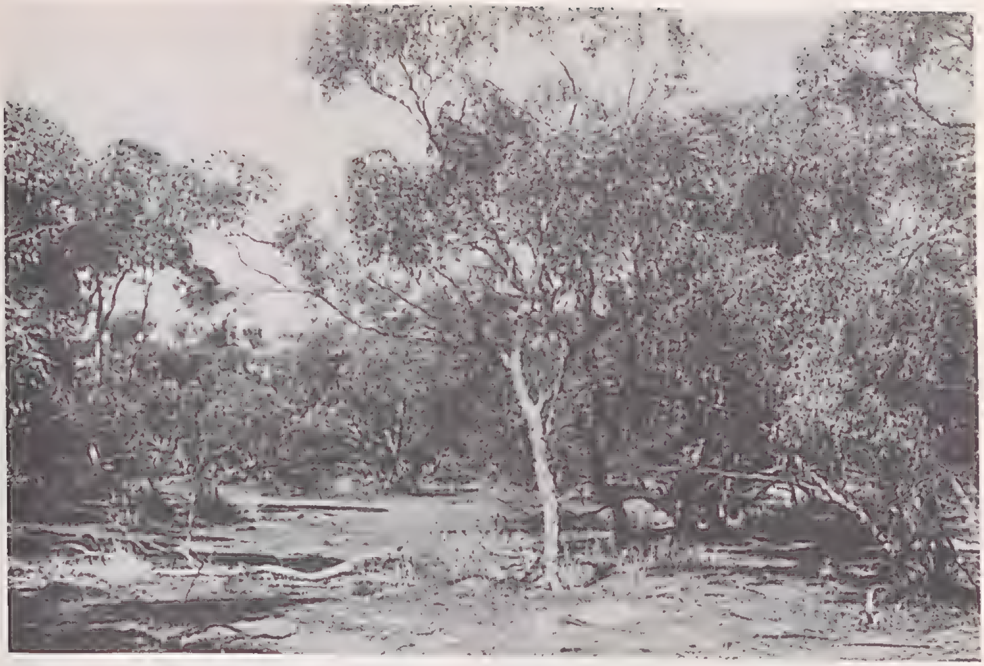


Figure 12. Black Box (*Eucalyptus largiflorens*) Woodland just south of Pooncarie on the Darling River.

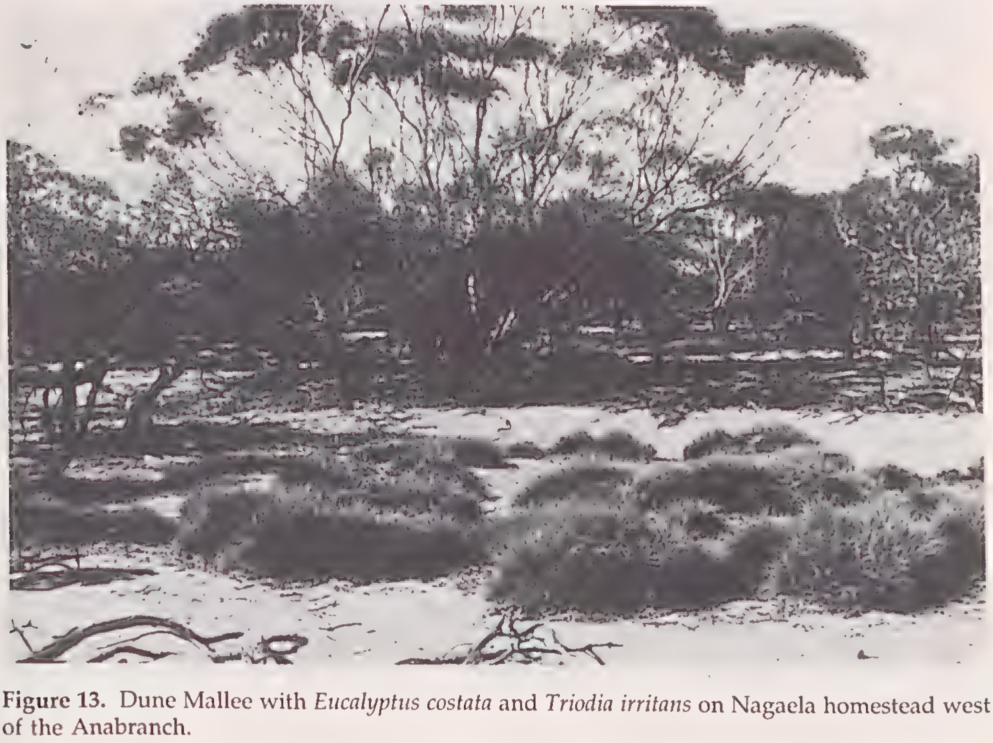


Figure 13. Dune Mallee with *Eucalyptus costata* and *Triodia irritans* on Nagaela homestead west of the Anabranch.

Species richness: (0.1 ha) 39.7 ± 4.6 (n= 6)
Landform: Raised areas of highly calcareous heavy soils with calcrete fragments
Habitat (photopattern): No dunes apparent and uniform mottled photopattern
Soil: Fine red sandy loam with calcrete nodules
Degradation/regeneration: Preferentially cleared because of its slightly better soil and because the dominant species do not resprout as readily as mallee does.The dominant species form clumps and this creates a mosaic pattern. *Alectryon* flowers irregularly and no seedlings were observed. Root suckers develop around parent plants but are highly palatable to sheep and rabbits and are kept grazed down. (Figure 14).

5. Arid Shrubland (mosaic of map unit 3 with 4)

Code: eS2H/cS2Z
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Dune Mallee (3) with Belah-Rosewood (4)
Habitat (photopattern): At least 70% of the area is dunefield but widely spaced with 4 in swales

6. Arid Shrubland (mosaic of map unit 4 with 3)

Code: cS2Z/eS2H
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Belah-Rosewood (4) with Dune Mallee (3)
Habitat (photopattern): Finer grained photopattern than 5, predominately 4, may have some dunes with mallee but too small to map

7. Arid Shrubland (mosaic of map units 4, 3 & 8)

Code: cS2Z/eS2H/kZ2F
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Belah-Rosewood (4) with Dune Mallee (3) and Black Bluebush (8)
Habitat (photopattern): Quite irregular, more patchy than 4 and with occasional open patches (8), each component too small to map separately

8. Black Bluebush

Map units: 8 (9, 10)
Code: kZ2F
Structural formation: Low shrubland
Height: 1–2 m
Cover: 10–30 %
Dominant species: *Maireana pyramidata, Rhagodia spinescens*
Understorey species: *Sclerolaena* spp., *Osteocarpum acropterum* var. *deminutum, Atriplex* spp.
Species richness: 35.4 ± 2.7 (n= 9)

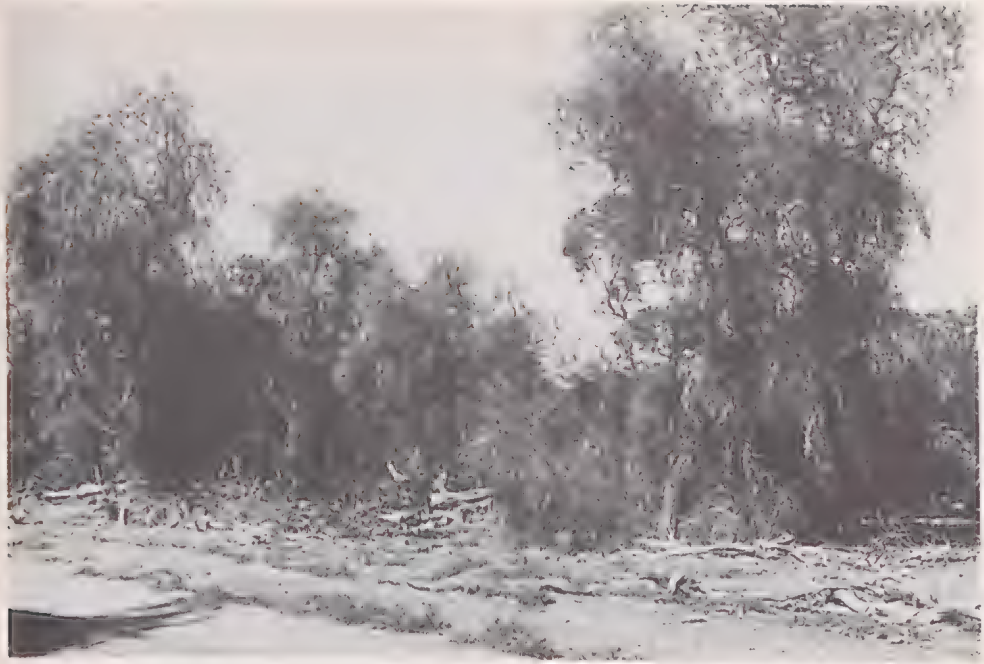


Figure 14. Stand of *Casuarina pauper*.

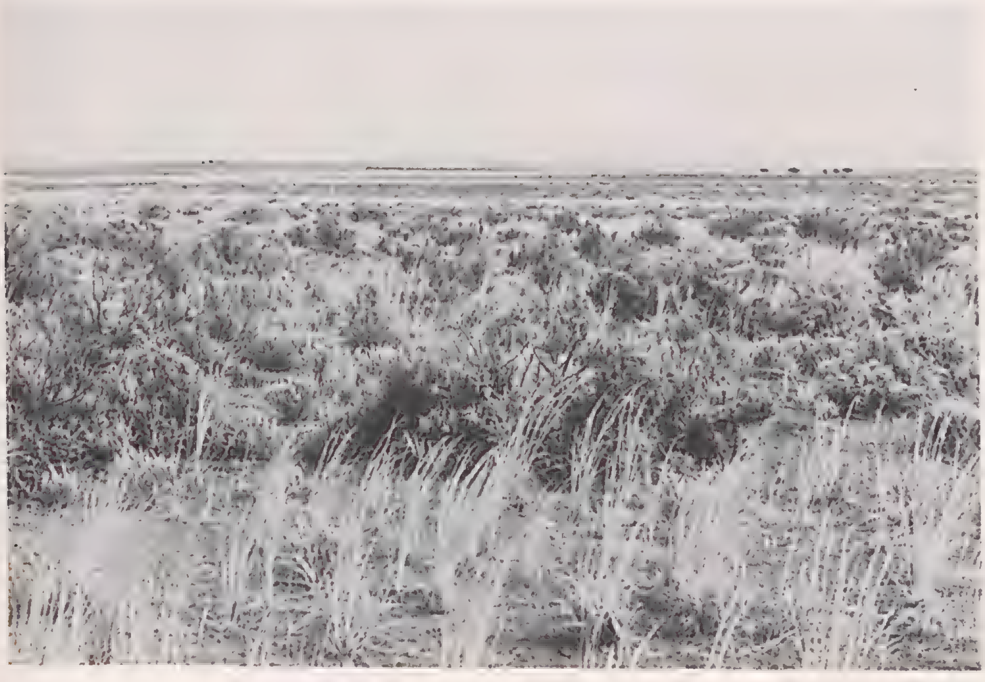


Figure 15. *Maireana pyramidata* shrubland on 'Nulla' homestead north of Lake Victoria.

Landform: Clay plain
Habitat (photopattern): Some scattered clumps of 4
Soil: Calcareous red loamy sand, red-brown loam, consistently with calcretions in top 40 cm
Degradation/regeneration: Under grazing no regeneration occurs. Sheep browse these perennial shrubs but goats and rabbits are more damaging, often ring-barking the main stems and excavating and eating the roots. Degraded areas may be invaded by *Nitraria billardieri.* (Figure 15).

9. Bluebush, Pearl Bluebush

Map unit: 9
Code: kZ2F
Structural formation: Low shrubland
Height: 1–2 m
Cover: 10–30 %
Dominant species: *Maireana sedifolia*
Understorey species: *Erodium* spp., *Tetragonia tetragonioides, Sclerolaena* spp.
Species richness: (0.1 ha) 24.7 ± 1.1 (n= 5)
Habitat (photopattern): More open than 8, some clumps of 4
Landform: Typically upslope of Black Bluebush on clay plain
Soil: Red sandy loam with nodules of calcrete in the top horizon
Degradation/regeneration: As for Black Bluebush. This shrubland also occurs with a mallee overstorey in restricted areas west of the Anabranch. (Figure 16).

10. Lunette Shrubland

Map unit: 10
Code: kZ2F
Structural formation: Low shrubland
Height: 0.8–2 m
Cover: 10–30 %
Dominant species: *Maireana pyramidata, M. appressa*
Understorey species: *Sclerolaena* spp., *Atriplex* spp.
Species richness: (0.1 ha) No estimate
Habitat (photopattern): Gypseous dunes associated with lakes, including lunettes
Landform: Gypseous dunes associated with lakes, including lunettes
Soil: Saline gypseous clay mantling sand core
Degradation/regeneration: These landforms can erode to create spectacular features such as the Walls of China at Lake Mungo. Such erosion usually follows periods of over-grazing and trampling. Few perennial plants persist on lunettes and no regeneration was observed. (Figure 17).

11. Bladder Saltbush

Map units: 11 (12, 15)
Code: kZ2F
Structural formation: Low shrubland
Height: 0.2–1 m
Cover: 10–30 %

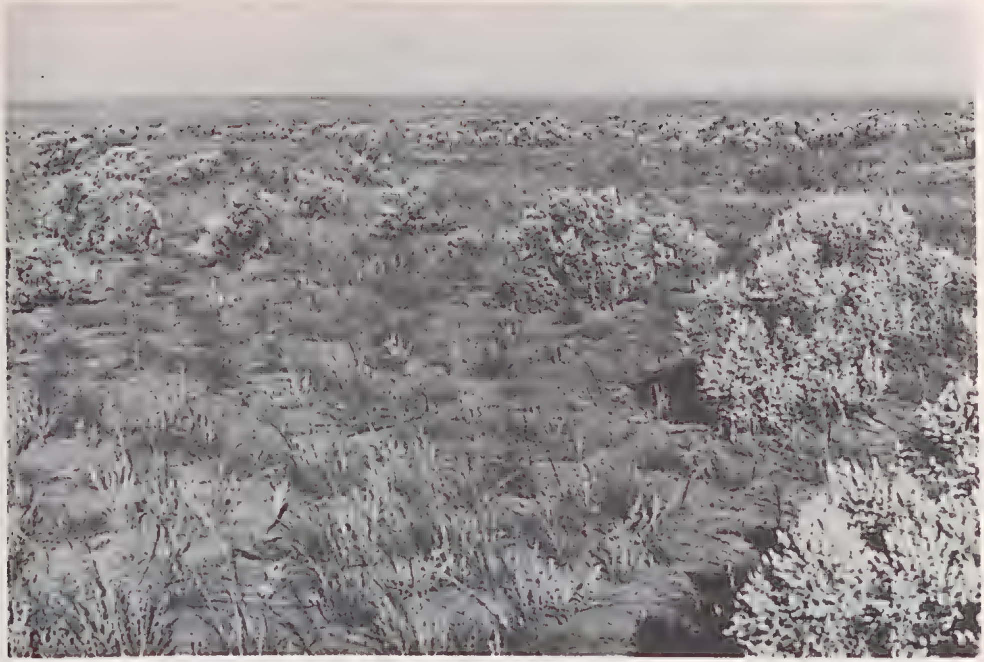


Figure 16. A stand of Bluebush (*Maireana sedifolia*) north-east of Lake Victoria.

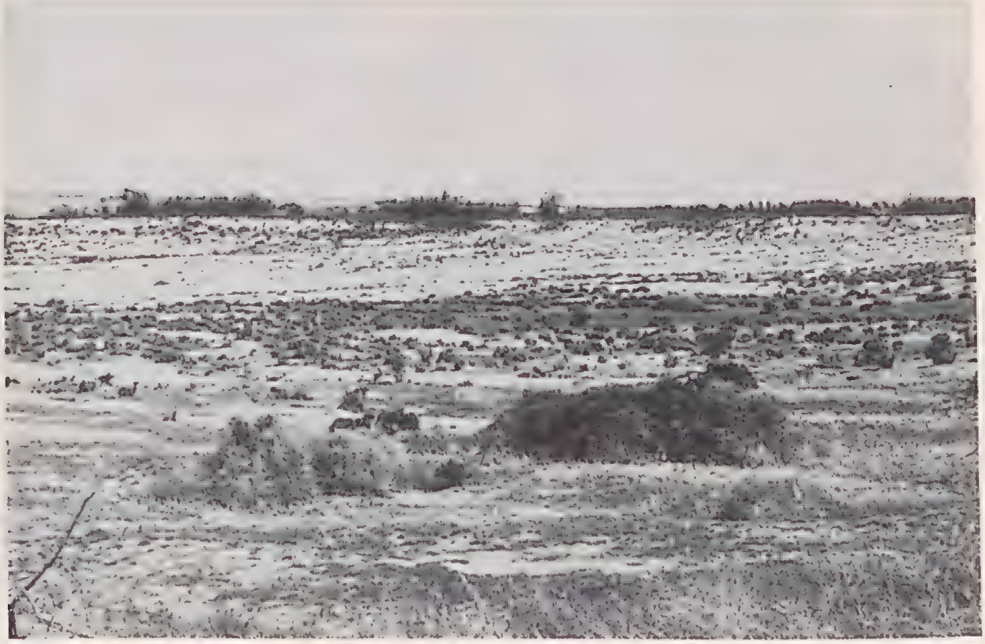


Figure 17. Lunette of Lake Victoria with scattered shrubs of *Maireana pyramidata*.

Dominant species: *Atriplex vesicaria*
Understorey species: *Sclerostegia tenuis, Pachycornia triandra, Osteocarpum acropterum* var. *deminutum, Disphyma clavellatum*
Species Richness: (0.1 ha) 18.1 ± 2.1 (n= 5)
Landform: Lower Alluvium, alluvial plains
Habitat (photopattern): Fine-grained, often with pronounced curvilinear patterns from paleochannels
Soil: Grey-brown clay loam, surface cracked
Degradation/regeneration: Often heavily grazed, affecting the shrub vitality and cover. No seedling regeneration was observed in the study area throughout the survey period. Degraded areas may be invaded by *Nitraria billardieri.* (Figure 18).

12. Pigface – Samphire

Map units: 12 (11, 15)
Code: kZ1F
Structural formation: Low open-shrubland.
Height: 0.1–0.4 m
Cover: <10%
Dominant species: *Disphyma clavellatum, Sclerostegia tenuis* [may have overstorey of *E. largiflorens*]
Understorey species: *Annual Atriplex, Sclerolaena* spp.
Species richness: No estimate
Landform: Saline flats
Habitat (photopattern): Associated with 15
Soil: Pale cream-grey cracking clay
Degradation/regeneration: It is generally considered that *Disphyma clavellatum* is now much reduced in abundance since settlement, due to grazing and trampling (Cunningham et al. 1981). This community may grade into saltpan. (Figure 19).

13. Canegrass Swamp

Map units: 13 (11, 15)
Code: yG3F
Structural formation: Grassland
Height: 1–3 m
Cover: 30–70 %
Dominant species: *Eragrostis australasica, Muehlenbeckia cunninghamii*
Understorey species: Usually absent
Species richness: (0.1 ha) No estimate
Landform: Depressions in clay plain
Habitat (photopattern): With scattered trees of *Eucalyptus largiflorens*
Soil: Grey cracking clay
Degradation/regeneration: Subject to intermittent flooding where water remains several months. May have scattered trees of *Eucalyptus largiflorens*. Important wildlife habitat particularly for nesting waterbirds, although it can also harbour feral pigs.

14. Sedge Swamp

Map unit: 14
Code: gG3F.

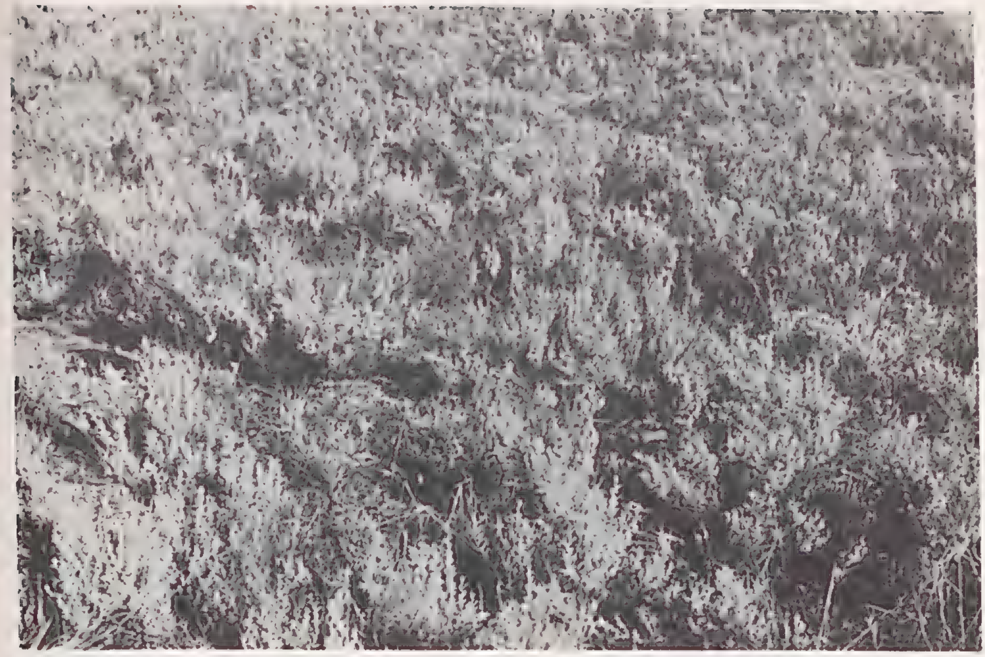


Figure 18. *Atriplex vesicaria* stand with *Sclerostegia tenuis* just west of Wentworth.

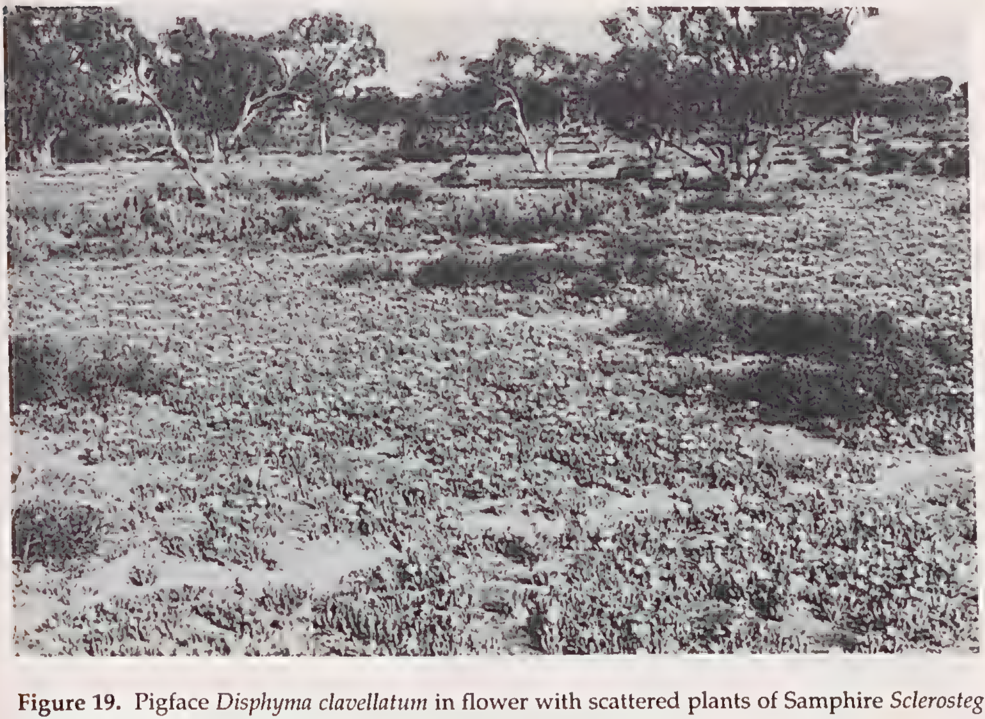


Figure 19. Pigface *Disphyma clavellatum* in flower with scattered plants of Samphire *Sclerostegia tenuis* with Black Box *Eucalyptus largiflorens.*

Structural formation: Sedgeland
Height: 0–0.5 m
Cover: 30–70 %
Dominant species: *Eleocharis pallens*
Understorey species: Usually absent
Species richness: (0.1 ha) No estimate
Landform: Flats or depressions within Riverine Forest, margins of swamps, claypans and lakebeds
Habitat (photopattern): Flats within RiverineForest
Soil: Variety of clay soil.
Degradation/regeneration: Responds quickly to rain and grows throughout the year if water is available. Only is grazed by stock if other more palatable species are unavailable.

15. Saltpan, Lakebed

Map units: 15, Lake
Code: kF2F
Structural formation: Open herbland
Height: 0–0.2 m
Cover: 10–30 %
Dominant species: *Sclerostegia tenuis, Muehlenbeckia cunninghamii, M. horrida* (edges)
Understorey species: *Atriplex leptocarpa, A. pseudocampanulata, Disphyma clavellatum*
Species richness: (0.1 ha) No estimate
Landform: Saltpan or clay flat often areas of groundwater discharge, some lakebeds
Habitat (photopattern): Saltpan or clay flat
Soil: Highly saline gypseous flats, fine-grained clay, large desiccation cracks
Degradation/regeneration: Many of the larger lakes are now cultivated and in such cases, all native vegetation has been destroyed. (Figure 20).

Plant communities too small to be shown as separate map units

Sand Plain Mallee

Map units: 3, 5, 6, 7
Code: eS2H
Structural formation: Tall shrubland
Height: 6–10 m
Cover:10–30 %
Dominant species: *Eucalyptus oleosa, E. socialis, E. gracilis*
Understorey species: *Chenopodium curvispicatum, Ptilotus exaltatus* var. *exaltatus, Olearia muelleri*
Species richness: (0.1 ha) 23.7 ± 1.1 (n= 5)
Landform: Sand plain, sand ridges
Soil: Calcareous sandy red earth, red duplex soil
Degradation/regeneration: More easily cleared than Dune Mallee because of flatter topography and heavier soil. No eucalypt seedling regeneration noted.

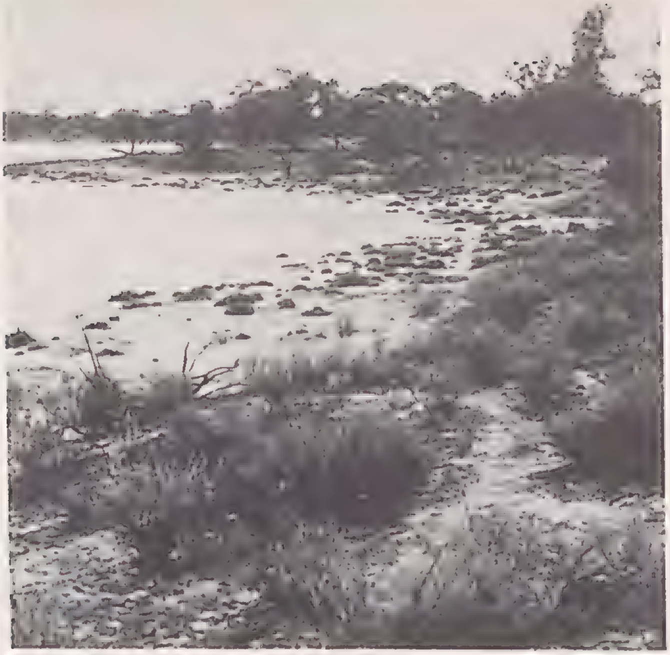


Figure 20. Edge of Salt Lake north of Lake Victoria with *Muehlenbeckia horrida* around margin.

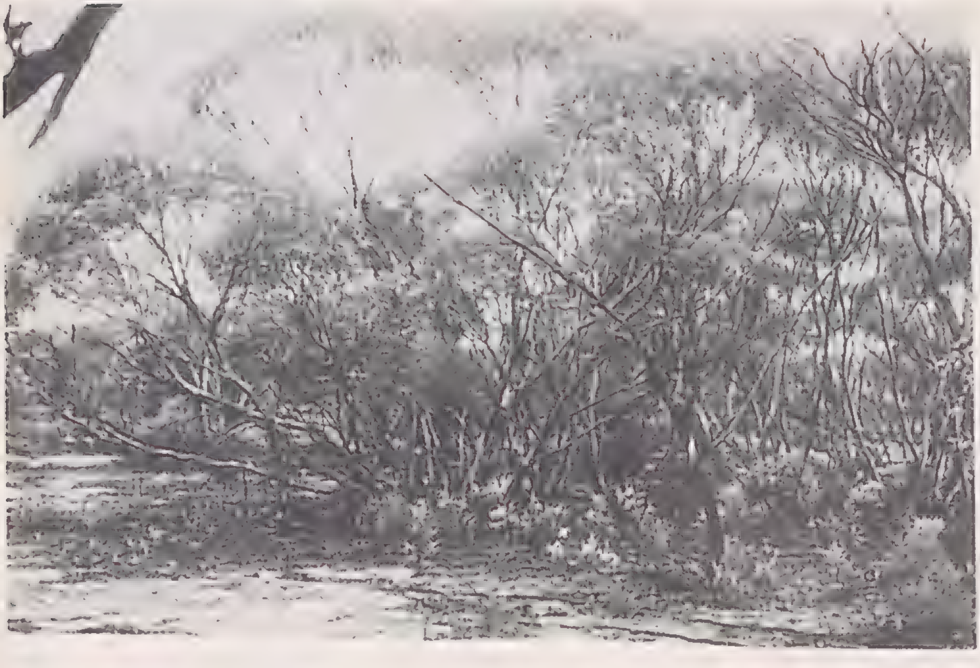


Figure 21. Swale mallee with *Eucalyptus gracilis* in flower.

Swale Mallee

Map units: 3, 5, 6, 7
Code: S2H
Structural formation: Tall shrubland
Height: 2–10 m
Cover: 10–30 %
Dominant species: *Eucalyptus gracilis, E. dumosa*
Understorey species: *Enchylaena tomentosa, Dissocarpus paradoxus, Senna artemisioides, Sclerolaena* spp.
Species richness: (0.1 ha) 34.2 ± 1.4 (= 5)
Landform: Swales between sand dunes and deflated sand plains
Soil: Calcareous red sand
Degradation/regeneration: More subject to clearing than the dune mallee. Often the sites for watering points and ground tanks and therefore prone to trampling and over-grazing. (Figure 21).

Mixed Woodland, Callitris Woodland

Map units: 4, 11
Code: pM2S
Structural formation: Open woodland
Height: 8–12 m
Cover: 10–30 %
Dominant species: *Callitris glaucophylla, Hakea leucoptera, Hakea tephrosperma, Myoporum platycarpum*
Understorey species: *Maireana pyramidata*
Species richness: no estimate
Landform: Sandy rises adjacent to riverine flats, source-bordering dunes
Soil: Deep loose sandy soil. On sandhills along the Murray and lowermost part of the Darling, Murray Pine, *Callitris preissii* subsp. *murrayensis* occurs and also much *C. preissii–C. glaucophylla* hybridisation (L.A.S. Johnson pers. comm.)
Degradation/regeneration: often cleared for valuable timber trees and only identifiable by the landform and scattered remnant trees. Further east of the mapped area this landform is often cultivated for wheat and other cereal crops. Similar woodland may be found on sandy rises on the western sides of lakes as well, for example west of Popiltah Lake. Such stands are always of small area and cannot be mapped at the scales employed here.

Acacia Shrubland

Map units: 1, 2, 4
Code: wS3F
Structural formation: Tall shrublan
Height: 2–6 m
Cover: 30–70%
Dominant species: *Acacia victoriae, Dodonaea, Acacia oswaldii*
Understorey species: *Sclerolaena* spp., *Maireana* spp.
Species richness: No estimate
Landform: Sandy rises such as source-bordering dunes which extend along rivers and major streams, creek beds and banks in a variety of landforms

Soil: Red sandy soil
Degradation/regeneration: Remnant trees of *Myoporum platycarpum, Hakea leucoptera, Hakea tephrosperma, Callitris glaucophylla* and *Callitris preissii* subsp. *murrayensis* may occur. This may represent highly disturbed areas that previously supported *Callitris* woodland. The dominant species may be mainly the 'woody weeds' which are invasive, colonising, native species.

Lignum Swamp

Map units: 2, 12, 14
Code: xS4F
Structural formation: Closed scrub
Height: 2–8 m
Cover: 70–100 %
Dominant species: *Muehlenbeckia cunninghamii* (*Eucalyptus camaldulensis, E. largiflorens* around edges)
Understorey species: Usually absent
Species richness: (0.1 ha) No estimate
Landform: Depressions with impounded water
Soil: Heavy clay
Degradation/regeneration: Very important wildlife habitat particularly for nesting waterbirds. Regenerates readily under favourable flood conditions. (Figure 23).

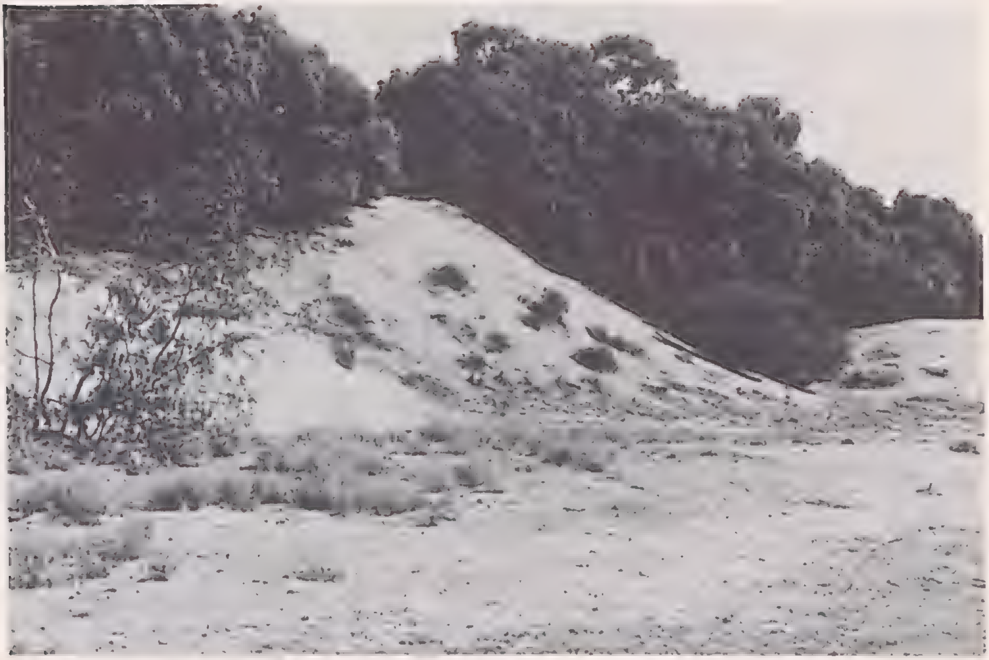


Figure 22. Acacia Shrubland on a source-bordering dune on the eastern bank of the Darling River northwest of Pooncarie.

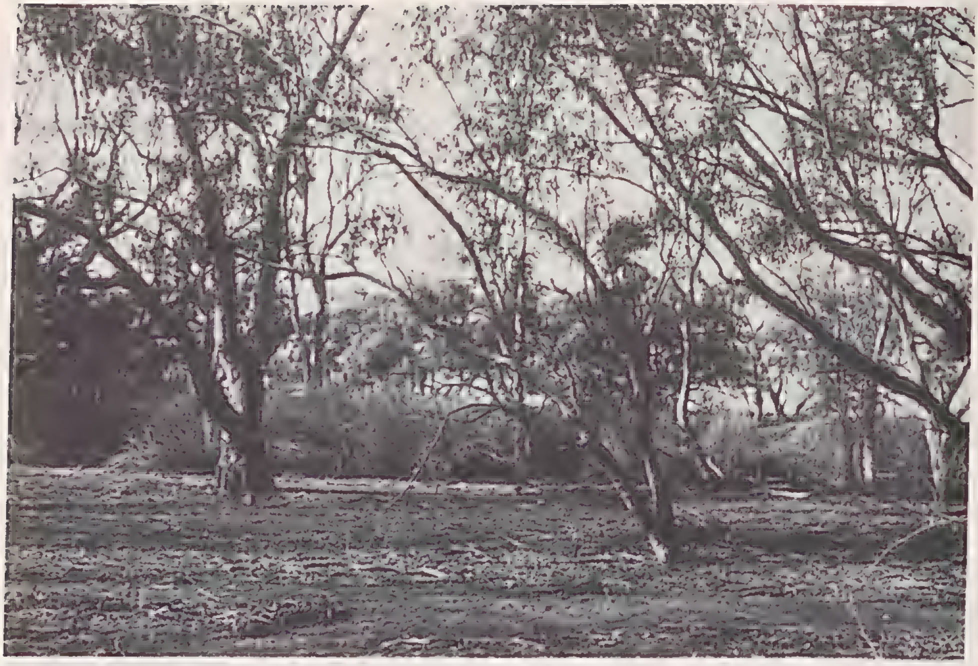


Figure 23. A small Lignum (*Muehlenbeckia cunninghamii*) swamp ringed by River Red Gums (*Eucalyptus camaldulensis*).

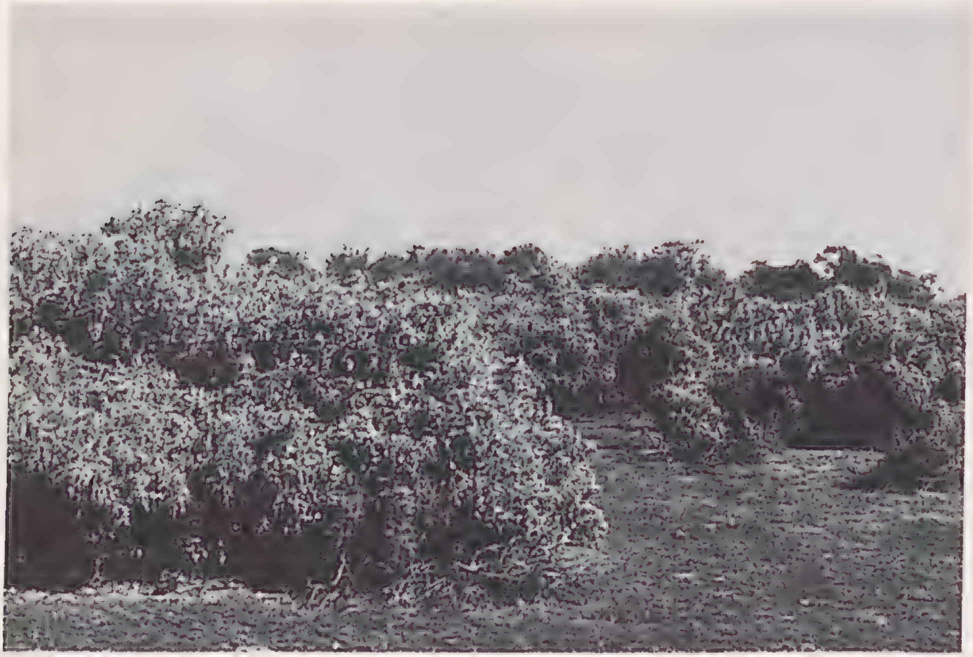


Figure 24. Stand of Old Man Saltbush (*Atriplex nummularia*) near the junction of the Darling and Murray rivers.

Old Man Saltbush

Map units: 2
Code: kS3F
Structural formation: Tall shrubland
Height: 1–2 m
Cover: 30–70 %
Dominant species: *Atriplex nummularia, Rhagodia spinescens,* [*Eucalyptus largiflorens*]
Understorey species: *Atriplex* spp., *Sclerolaena* spp.
Species richness: (0.1 ha) No estimate.
Landform: River flat
Soil: Clay soils
Degradation/regeneration: Grades into *Maireana pyramidata* shrubland away from the river. These deeply rooted shrubs can withstand severe drought and also tolerate flooding, but can be decimated by heavy continuous grazing. Only small relict stands remain of what were more extensive stands (Cunningham et al. 1981). (Figure 24).

Floristic composition

Appendix I contains the list of flowering plant species identified from sites or collections on the Ana Branch – Mildura map sheet area. The families are arranged alphabetically within orders, and genera alphabetically within families, and the species alphabetically within genera. An asterisk indicates an exotic species. Authorities are not given and can be found in Harden (1990), Jacobs & Lapinpuro (1986) or Jacobs & Pickard (1981).

Table 4 lists the floristic composition of broad vegetation categories for the mapped area. The table is modified from an earlier table (Fox 1984) which was based on a set of sites on the mapped area. The totals shown in the first column are the original site totals and in brackets the total recorded for all sites and collections for the map sheet. A total of 266 native species and exotic species were recorded for the map sheet area. This is 44% of the total expected for the Far South Western Plains (Table 1). The incidence of exotics, at 11% of the total, is relatively low compared to disturbed sites in the east (see Table 1, Fox & Fox 1986). The total species pool comes from 60 families of vascular plants however, ten families account for 86% of this richness. Principal among these are the Chenopodiaceae (78 species), Asteraceae (51 species) and Poaceae (40 species).

The total species data for the broad vegetation types in Table 4 indicate their relative richness. Mallee is markedly richer than the other types although it does not have proportionally more genera or families represented. Also these totals are composites from several sites. Single site collections for mallee can be quite low, depending on seasonal rainfall.

Table 4. Summary of floristic data from Ana Branch – Mildura map (from Fox 1984), with updated totals shown in the first column in brackets.

	Total		Mallee	Chenopod shrubland	Lakebed	Riverine forest	Casuarina woodland	Acacia shrubland
Species	188	(299)	96	55	44	37	33	30
Exotic	13	(33)	4	5	1	3	3	4
Genera	99	(191)	54	28	31	21	26	21
Spp./gen.	1.9	(1.6)	1.8	2	1.4	1.8	1.3	1.4
Families	37	(60)	27	10	13	10	15	14
Gen./fam.	2.7	(3.2)	2	2.8	2.4	2.1	1.7	1.5
Chenopodiaceae	62	(78, 26.3%)	26%	65.5%	43.2%	67.6%	33.0%	30.0%
Asteraceae	20	(51, 17.2%)	12.5	10.9	11.4	2.7	6.1	6.7
Fabaceae	19	(27, 9.1%)	11.5	5.5	4.6	8.1	12.1	20.0
Poaceae	19	(40, 13.5%)	9.4	9.1	11.4	2.7	12.1	6.7
Myrtaceae	10	(13, 4.4%)	6.3	-	6.8	5.4	-	3.3
Myoporaceae	5	(8, 2.7%)	5.2	-	-	-	3	3.3
Solanaceae	5	(8, 2.7%)	2.1	-	2.3	-	3	3.3
Amaranthaceae	4	(7, 2.4%)	3.1	-	2.3	-	-	-
Zygophyllaceae		(11, 3.7%)	-	-	-	-	-	-
Brassicaceae		(12, 4.0%)						
Sub-total	144	(255, 85.9%)	76.1	91.0	82.0	86.5	69.3	70.0

Modifications to the vegetation

Grazing

It was not within the scope of this study to incorporate a detailed investigation into the impact of grazing on the vegetation of the region. However, with grazing being the principal pastoral activity for much of the mapped area, it would be an oversight not to comment on observed impacts. Clearly there has been a deleterious impact on the vegetation of the region from the millions of both husbanded and feral animals that now graze and browse where once smaller nomadic populations of native grazers and browsers had limited impact. The provision of additional water supplies for the husbanded animals has also led to heightened populations of both feral and native animals through good and dry times. Perhaps most destructive of all has been the sustained high numbers of rabbits throughout the study area. Even in periods of drought, although their numbers are much reduced, foci of reinvasion persist and as soon as the country improves their numbers explode. Rabbits and goats are particularly destructive to native perennial plants because, as well as foliage, they eat bark and roots, commonly leading to the death of the plants.

In Kinchega National Park, north of the mapped area, the New South Wales National Parks and Wildlife Service conducted a long-term investigation of the interactions of kangaroos and sheep (Caughley, Shepherd & Short 1987). Within the National Park, large exclosures were maintained and the biomass and composition of the vegetation monitored. Similar plots were maintained on an adjacent property on Lake Tandou. Robertson (1987) found that in terms of biomass, extreme weather events overshadow the impact of grazing. There was no significant difference in composition between pasture grazed by kangaroos alone and by sheep and kangaroos, however trends may be blurred by the long history of sheep at all sites.

Fire

The usual fire frequency in arid and semi-arid rangelands is every 10 to 15 years (McArthur 1972). However, after years of above-average rainfall, fuel accumulates quickly. There have been several recorded extensive fires in western NSW, all following periods of above-average rainfall. Most of the mapped area showed no evidence of recent fire. East of the Darling there were extensive fires in 1974 but these did not spread west of the river. Recently there have been some experimental fires in the mallee west of the Anabranch of the Darling to promote the long-term survival of the mallee fowl.

Many species of plants in the region are resistant to fire, in that they have the ability to resprout. However, the important grass of much of the mallee country, *Triodia irritans*, is killed by fire and must regenerate from seed in the soil to persist at the site. CSIRO has had a long-term fire research program underway just east of Pooncarie (east of the mapped area) (Noble 1989).

Flooding and drought

Parts of the area, adjacent to the major streams, are subject to flooding from the major rivers. This has a direct impact on the vegetation, particularly on the River Red Gum forests and the Black Box woodlands. Recruitment of both dominant tree species only occurs in the conditions immediately after flooding.

The composition of the annual or short-lived perennial species in the ground layer is largely determined by the amount and seasonal distribution of rainfall (Fox in press). In drought years this stratum of the vegetation may be missing. With the onset of rain, seed stored in the soil germinates and quickly establishes a herbaceous ground layer. The composition of this herb stratum is determined by the duration and amount of rain in the season and the follow-up conditions. Most of the weed species found in the region are herbaceous plants that may dominate the ground stratum in good seasons.

Soil chemistry

Appendix II is modified from Table 2 in Fox (1984), it summarizes the chemical status of soil collected at a range of sites in the south-west of New South Wales, including sites on the Ana Branch – Mildura map sheet area. These give an indication of the regional trend in soil chemistry, related to broad vegetation types. Additional sites sampled subsequently on the map area are included in italics.

There is considerable variation in the chemical composition of all the soils sampled. In particular, the calcium content fluctuates widely. The vegetation types used in Appendix II are arranged in roughly increasing concentration of lime in the soil. Highest calcium content is found in the soil under Black Box, *Eucalyptus largiflorens*, however, it is also the most variable.

The soil pH is generally around neutrality (7.0), the most alkaline soil was that under *Alectryon* shrubland (mean 7.8 ± 0.2), and the most acidic soil was associated with *Callitris* woodland (5.96 ± 0.30).

Conservation of vegetation

As stated in the Introduction, there is only one nature reserve in the mapped area, that is Nearie Lake Nature Reserve, gazetted in 1973 and 4347 ha in area. There is also one national park and it extends onto part of the eastern edge of the Mildura sheet. This is Mallee Cliffs National Park, gazetted in 1977 with extensions in 1978 and 1983 to a total of 57,969 ha. North of the Ana Branch sheet is Kinchega National Park, first gazetted in 1967 with extensions in 1968, 1972, 1974 and1982, and totalling 44,182 ha in area. As a proportion of the mapped area the formal reservations (Nearie Lake and about one eighth of Mallee Cliffs National Park) represent less than 1% of the area. For the whole of the Western Division formal reserves (six national parks, eight nature reserves, two historic sites and one Aboriginal area) total over 760,000 ha. Recent acquisitions will bring the total to 940,000 ha, or almost 3% of the Western Division (Pressey & Nicholls 1991). This indicates the discrepancy between reserves in the north of the Division and the paucity of reserves in the south. East of the mapped area, and within the Western Division, is also Mungo National Park, but all of the other reserves are north of 33°S.

Pressey & Nicholls (1991) have considered the adequacy of the reserve system in north-western NSW. Using land systems maps, they estimated that nearly 6% of their study area (north-western NSW) was needed for at least one representation of each land system. Given that there are unique associations such as the Bladder Saltbrush (*Atriplex vesicaria*) with Samphire (*Sclerostegia tenuis*) found only in south-western NSW, which are currently not represented in the reserve system, there is an urgent need to identify and acquire suitable sites there.

Significant vegetation types

Although very widespread through much alluvial country of southern Australia, the woodlands of *Eucalyptus largiflorens* are of scientific interest because they comprise stands of single species of *Eucalyptus* trees. The usual pattern in most woodlands and forests dominated by eucalypts is for a mixture of at least two, and commonly more, species occurring together.

The mixed woodlands with species of *Callitris, Acacia, Hakea, Myoporum,* etc. that previously occurred on source-bordering dunes and other sandy rises, have been considerably reduced by clearing. In a landscape with very little good timber, these trees were a source of material for fence posts, sheds and houses.

The stands of *Atriplex nummularia* (Old Man Saltbush), either as understorey to *E. largiflorens* woodland or as tall shrublands, are now much reduced from their previous extent. However, some very fine stands occur at the junction of the Darling and the Murray Rivers. Their decline is in part a result of grazing, but also a consequence of a past clearing program because they harbour rabbits. Isolated individual shrubs are testament to their previous wider distribution.

The low shrubland of *Atriplex vesicaria* with *Sclerostegia tenuis* and *Pachycornia triandra* is particularly well developed on the lower alluvium west of Wentworth. It is not represented in any conservation reserve.

Rare species

Table 5 lists the species from the Far South West Plains that are considered rare or endangered (Leigh et al. 1981, Briggs & Leigh 1988). Recently the restricted species of the Western Division have been reexamined (Pressey, Cohn & Porter 1990), and their Category and Priority classes are also given in Table 5.

Table 5. Species of flowering plants, occurring in the Far South Western Plains, and listed as being rare or endangered by Briggs & Leigh (1988). Those in square brackets were listed by Leigh, et al. 1981), the Risk Codes[1] are as follows: **2** maximum geographic range of 100 km, **3** range over 100 km but restricted to highly specific habitats, **X** Presumed extinct, **E** Endangered species in serious risk of disappearing, **V** Vulnerable species, at risk over a longer period; **R** Rare species, not currently considered endangered or vulnerable; **C** Species known to be represented within a National Park or other proclaimed reserve; **a** adequately reserved; **-** adequacy of reservation unknown; and [2] Category and Priority according to Pressey et al. (1990).

Family	Species	Risk Code[1]	Category[2]	Priority[2]
Asteraceae	*Acanthocladium dockeri*	3X	3A(X)	2
Chenopodiaceae	*Atriplex papillata*	[3RC]	3A	3
Eriocaulaceae	*Eriocaulon australasicum*	2VCa		
Fabaceae (Faboideae)	*Swainsona laxa*	3VCa	3A	2
Gyrostemonaceae	*Codonocarpus pyramidalis*	3RC-	3A(X)	2
Fabaceae (Mimosoideae)	*Acacia carnei*	3RC-	3A	2
	Acacia rivalis	[3RC]	3A	3

The Categories recognised by Pressey et al. (1990) combine both the species geographic range and the status of its populations. 3A is 'restricted distribution in the Western Division and also occurring interstate, with small range and/or few records interstate'. (X) is presumed extinct in the Western Division.

Acanthocladium dockeri (Spiny Everlasting) is a small rigid shrub only collected during the last century from sandhills near the lower Darling River, it is probably extinct. *Atriplex papillata* is a prostrate forb. The few collections of this species are from the extreme south-west of the South Western Plains (not FSWP as previously thought) where it occurs around the margins of salt lakes. *Eriocaulon australasicum* (Pipewort) is a small annual forb known only from one collection in 1853 from near Balranald, east of the mapped area. *Swainsona laxa* (Yellow Darling Pea) has been recorded from Menindee, north of the mapped area and from Euston, just east of the mapped area on the Murray River. It has also been collected from Mount Hope in central NSW *Codonocarpus pyramidalis* (Native Poplar) is a tall shrub or small tree. It was collected from the Pooncarie district, just east of the mapped area, earlier this century and has not been recorded since. Both species of *Acacia*, *A. carnei* and *A. rivalis* are from near Broken Hill, to the north of the mapped area.

Conclusions

The far southwest of New South Wales, covered by the Ana Branch – Mildura vegetation map, is an alluvial landscape with relatively few plant communities. Some communities are restricted to either aeolian, fluvial or lacustrine landforms but there is considerable sharing of species. Fifteen map units were recognised but some communities were unmappable because their small areal extent precludes them from representation at this scale.

The vegetation of western New South Wales is relatively poorly conserved in reserves compared with that of the eastern portion of the state, and the southwest is not as well served by vegetation reserves as the north. Of the area mapped less than one percent is in a conservation reserve. This is in spite of several significant vegetation types and the more pervasive need to conserve representative samples of all our vegetation types before they are too degraded by the combined assaults of domestic and feral animals.

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APPENDIX I

Flowering plants recorded from the Ana Branch – Mildura map sheet area. Names are those currently in use by the National Herbarium of New South Wales and authorities are given in Harden (1990), Jacobs & Lapinpuro (1986) or Jacobs & Pickard (1981) except as given in the text.

GYMNOSPERMS

CUPRESSACEAE
Callitris glaucophylla
Callitris preissii subsp. *verrucosa*
Callitris preissii subsp. *murrayensis*

ANGIOSPERMS – DICOTYLEDONS

AIZOACEAE
Disphyma clavellatum
Mesembryanthemum nodiflorum
Mollugo cerviana
**Psilocaulon tenue*
Sarcozona praecox
Tetragonia tetragonoides
Tranthema triquetra
Zaleya galericulata subsp. *galericulata*

AMARANTHACEAE
Alternanthera denticulata
Amaranthus grandiflorus
Amaranthus macrocarpus
Ptilotus exaltatus var. *exaltatus*
Ptilotus obovatus
Ptilotus polystachyus
Ptilotus seminudus

APIACEAE
Daucus glochidiatus

ASCLEPIADACEAE
Leichhardtia australis

ASTERACEAE
Actinobole uliginosum
Angianthus tomentosus
Brachycome ciliaris var. *ciliaris*
Brachycome ciliaris var. *lanuginosa*
Brachycome heterodonta var. *heterodonta*
Brachycome lineariloba
**Calendula arvensis*
Calocephalus sonderi
Calotis cuneifolia
Calotis cymbacantha
Calotis hispidula
**Carthamus tinctorius*
**Centaurea melitensis*
Centipeda cunninghamii
Centipeda thespedioides
Chthonocephalus pseudevax
Craspedia pleiocephala
Craspedia uniflora
**Dittrichia graveolens*
Eriochlamys behrii
Gnaphalium sphaericum
Helichrysum semipapposum
Helipterum corymbifolium
Helipterum floribundum
Helipterum jessenii
Helipterum moschatum
Helipterum pygmaeum
Helipterum uniflorum
**Hypochoeris glabra*
Isoetopsis graminifolia
Ixiolaena leptolepis
Millotia greevesii subsp. *greevesii* var. *greevesii*
Minuria cunninghamii
Myriocephalus stuartii
Olearia muelleri
Olearia pimeleoides var. *pimeleoides*
Olearia subspicata
**Onopordum acanthium*
**Onopordum acaulon*
Podolepis capillaris
Rutidosis helichrysoides
Senecio glossanthus
Senecio gregorii
Senecio quadridentatus
**Sonchus asper*
**Sonchus oleraceus*
Toxanthes perpusilla
Vittadinia triloba/cuneata complex
Vittadinia cuneata subsp. *cuneata* f. *cuneata*
Vittadinia cuneata var. *morrisii*
Waitzia acuminata
**Xanthium occidentale*

BORAGINACEAE
**Echium plantagineum*
Halgania cyanea
Heliotropium curassavicum
Heliotropium supinum
Omphalolappula concava
Plagiobothrys plurisepaleus

BRASSICACEAE
**Alyssum linifolium*
Arabidella nasturtium
Arabidella trisecta
Blennodia canescens
**Brassica tournefortii*

**Carrichtera annua*
Geococcus pusillus
Harmsiodoxa blennodiodes
Lepidium phlebopetalum
Phlegmatospermum cochlearinum
**Sisymbrium erysimoides*
Stenopetalum lineare

CACTACEAE
**Opuntia paraguayensis*

CAMPANULACEAE
Wahlenbergia fluminalis
Wahlenbergia gracilenta
Wahlenbergia tumidifructa

CAPPARIDACEAE
Apophyllum anomalum

CARYOPHYLLACEAE
Scleranthus minusculus
**Spergularia rubra*
Stellaria angustifolia

CASUARINACEAE
Casuarina pauper

CHENOPODIACEAE
Atriplex acutiloba
Atriplex angulata
Atriplex conduplicata
Atriplex eardleyae
Atriplex holocarpa
Atriplex leptocarpa
Atriplex limbata
Atriplex lindleyi
Atriplex nummularia
Atriplex pseudocampanulata
Atriplex pumilio
Atriplex semibaccata
Atriplex spongiosa
Atriplex stipitata
Atriplex suberecta
Atriplex velutinella
Atriplex vesicaria subsp. *calcicola*
Atriplex vesicaria subsp. *vesicaria*
Chenopodium cristatum
Chenopodium curvispicatum
Chenopodium desertorum subsp. *anidiophyllum*
Chenopodium desertorum subsp. *desertorum*
Chenopodium desertorum subsp. *microphyllum*
Chenopodium nitrariaceum
Chenopodium pumilio
Dissocarpus biflorus var. *biflorus*
Dissocarpus paradoxus
Dysphania glomulifera
Einadia hastata
Einadia nutans subsp. *nutans*
Enchylaena tomentosa
Halosarcia pergranulata subsp. *divaricata*
Maireana appressa
Maireana brevifolia
Maireana ciliata
Maireana coronata
Maireana decalvans
Maireana erioclada
Maireana georgei
Maireana microphylla
Maireana pentagona
Maireana pentatropis
Maireana pyramidata
Maireana radiata
Maireana schistocarpa
Maireana sclerolaenoides
Maireana sedifolia
Maireana trichoptera
Maireana triptera
Maireana turbinata
Malacocera tricornis
Osteocarpum acropterum var. *deminutum*
Pachycornia triandra
Rhagodia spinescens
Rhagodia ulicina
Salsola kali var. *kali*
Scleroblitum atriplicinum
Sclerolaena bicornis
Sclerolaena brachyptera
Sclerolaena calcarata
Sclerolaena decurrens
Sclerolaena diacantha
Sclerolaena divaricata
Sclerolaena intricata
Sclerolaena muricata var. *muricata*
Sclerolaena muricata var. *villosa*
Sclerolaena obliquicuspis
Sclerolaena parviflora
Sclerolaena patenticuspis
Sclerolaena stelligera
Sclerolaena tricuspis
Sclerolaena ventricosa
Sclerolaena stelligera
Sclerostegia tenuis
Threlkeldia proceriflora

CHLOANTHACEAE
Dicrastylis verticillata

CONVOLVULACEAE
**Convolvulus arvensis*
Convolvulus erubescens

CRASSULACAEAE
Crassula colorata var. *acuminata*
Crassula peduncularis
Crassula sieberiana subsp. *tetramera*

CUCURBITACEAE
**Cucumis myriocarpus*
Zehneria micrantha

EUPHORBIACEAE
Bertya cunninghamii
Beyeria opaca
Chamaesyce drummondii
Phyllanthus lacunarius

FABACEAE – Caesalpinoideae
Senna artemisioides nothosubsp. *coriacea*
Senna artemisioides subsp.*filifolia*
Senna artemisioides subsp. *petiolaris*

FABACEAE–Faboideae
Eutaxia microphylla var. *microphylla*
Glycyrrhiza acanthocarpa
Lotus cruentus
**Medicago minima*
**Medicago polymorpha*
Psoralea patens group.
Swainsona microphylla
Swainsona phacoides subsp. *phacoides*
Templetonia egena

FABACEAE–Mimosoideae
Acacia aneura
Acacia bivenosa subsp. *wayi*
Acacia brachystachya
Acacia burkittii
Acacia colletioides
Acacia havilandiorum
Acacia jennerae
Acacia ligulata
Acacia loderi
Acacia nyssophylla
Acacia oswaldii
Acacia stenophylla
Acacia wilhelmiana
Acacia tetragonophylla
Acacia victoriae

FRANKENIACEAE
Frankenia foliosa

GERANIACEAE
Erodium cicutarium
Erodium crinitum

GOODENIACEAE
Goodenia cycloptera
Goodenia fascicularis
Goodenia pinnatifida
Goodenia pusilliflora
Scaevola spinescens

GYROSTEMONACEAE
Codonocarpus cotinifolius

HALORAGACEAE
Haloragis glauca

LAMIACEAE
Mentha australis
**Salvia verbenaca*
Teucrium racemosum
Westringia rigida

LORANTHACEAE
Amyema linophyllum subsp. *orientale*
Amyema miquellii
Amyema preissii
Lysiana exocarpi subsp. *diamantinensis*

MALVACEAE
Abutilon otocarpum
Lawrencia glomerata
Radyera farragei
Sida ammophila
Sida filiformis
Sida intricata
**Sida rhombifolia*

MYOPORACEAE
Eremophila glabra
Eremophila latrobei
Eremophila maculata
Eremophila oppositifolia
Eremophila polyclada
Eremophila scoparia
Eremophila sturtii
Myoporum platycarpum

MYRTACEAE
Eucalyptus camaldulensis
Eucalyptus dumosa
Eucalyptus leptophylla
Eucalyptus gracilis
Eucalyptus largiflorens
Eucalyptus largiflorens x *E. populnea* subsp. *bimbil*
Eucalyptus costata
Eucalyptus incrassata
Eucalyptus oleosa
Eucalyptus oleosa x *E. socialis*
Eucalyptus populnea subsp. *bimbil*
Eucalyptus porosa
Eucalyptus socialis
Melaleuca lanceolata

NYCTAGINACEAE
Boerhavia coccinea
Boerhavia dominii

OXALIDACEAE
Oxalis perennans

PITTOSPORACEAE
Pittosporum phillyreoides

PLANTAGINACEAE
Plantago cunninghamii
Plantago drummondii
Plantago turrifera

PLUMBAGINACEAE
**Limonium lobatum*

POLYGONACEAE
**Emex australis*
Muehlenbeckia cunninghamii
Muehlenbeckia florulenta
Muehlenbeckia diclina
Muehlenbeckia horrida
**Rumex crystallinus*
Rumex tenax

PORTULACACEAE
Calandrinia eremaea
Calandrinia pumila
Calandrinia volubilis
Portulaca intraterranea
Potulaca oleracea

PROTEACEAE
Grevillea huegelii
Hakea leucoptera
Hakea tephrosperma

RANUNCULACEAE
Myosurus minimus
Ranunculus pentandrus var. *platycarpus*
Ranunculus pumilio

RHAMNACEAE
Cryptandra amara var. *longiflora*

RUTACEAE
Geijera parviflora

SANTALACEAE
Exocarpos aphyllus
Santalum acuminatum

SAPINDACEAE
Alectryon oleifolius subsp. *canescens*
[formerly *Heterodendrum*]
Atalaya hemiglauca
Dodonaea attenuata
Dodonaea bursariifolia
Dodonaea cuneata
Dodonaea triquetra
Dodonaea viscosa subsp. *angustissima*

SCROPHULARIACEAE
Morgania floribunda

SOLANACEAE
Duboisia hopwoodii
Lycium australe
**Nicotiana glauca*
Nicotiana simulans
Nicotiana velutina
Solanum coactiliferum
Solanum esuriale
Solanum nigrum

THYMELAEACEAE
Pimelea microcephala subsp. *microcephala*
Pimelea pauciflora
Pimelea trichostachya

URTICACEAE
Parietaria debilis

VERBENACEAE
**Phyla nodiflora*
**Verbena supina*

ZYGOPHYLLACEAE
Nitraria billardieri
Tribulus terrestris
Zygophyllum ammophillum
Zygophyllum apiculatum
Zygophyllum aurantiaceum
Zygophyllum glaucum
Zygophyllum eremaeum
Zygophyllum iodocarpum
Zygophyllum ovatum
Zygophyllum paradoxa
Zygophyllum simile

ANGIOSPERMS – MONOCOTYLEDONS

AMARYLLIDACEAE
Crinum flaccidum

ANTHERICACEAE
Thysanotus baveri

ASPHODELACEAE
Bulbine alata
Bulbine semibarbata

CYPERACEAE
Bulboschoenus medianus
Cyperus exaltatus
Cyperus gymnocaulos

JUNCACEAE
**Juncus acutus*

JUNCAGINACEAE
Triglochin calcitrapa

LOMANDRACEAE
Lomandra effusa

POACEAE
Agrostis avenacea
Amphipogon caricinus var. *caricinus*
Aristida contorta
Bromus arenarius
**Bromus rubens*
Chloris divaricata
Chloris truncata
Dactyloctenium radulans
Danthonia caespitosa
Danthonia eriantha
Diplachne fusca
Enneapogon avenaceus
Enneapogon nigricans
Enneapogon polyphyllus
Enteropogon acicularis
Eragrostis australasica
Eragrostis dielsii var. *pritzelii*
Eragrostis parviflora
Eriochloa crebra
Eriochloa pseudoacritricha
**Hordeum leporinum*
**Lamarckia aurea*
Paspalidium jubiflorum
Rostraria pumila
**Schismus barbatus*
Stipa elegantissima
Stipa mollis
Stipa nitida
Stipa nodosa
Stipa platychaeta
Sporobolus mitchellii
Tragus australianus
Triodia irritans
Tripogon loliiformis
Triraphis mollis
**Vulpia bromoides*
**Vulpia myuros*
Zygochloa paradoxa

TYPHACEAE
Typha domingensis

APPENDIX II

Summary of cation content, electrical conductivity and pH of vegetation sites. Exchangeable cations (Ca, Mg, K and Na) are expressed as m.e./100g, electrical conductivity (E.C.) is based on 1:2 mS/cm (modified from Fox 1984). Entries in *italics* are for sites sampled since 1984 on the map area. (mean ± s.e.)

Veg. Type	**n**	**Ca**	**Mg**	**K**	**Na**	**Ca/ Total Cations**	**E.C.**	**pH ($CaCl_2$)**
Mallee - Triodia	5	3.0±0.5	0.6±0.1	0.3±0.1	0.01±0	0.8±0.02	0.05±0.01	6.84±0.333
	5	*3.0+0.5*	*0.6+0.1*	*0.3+0.1*	*0.01+0*	*0.8+0.02*	*0.05+0.01*	*6.8±0.33*
***Callitris* woodland**	5	4.2±0.4	0.9±0.2	0.6±0.1	0.02±0.01	0.8±0.03	0.04±0.01	5.96±0.300
	-	-	-	-	-	-	-	-
***Alectryon* shrubland**	5	5.6±1.5	1.2±0.3	0.8±0.1	0.02±0.01	0.7±0.01	0.07±0.02	7.8±0.2
	5	*5.6+1.5*	*1.2+0.3*	*0.8+0.1*	*0.02+0.01*	*0.7+0.01*	*0.07+0.02*	*7.8+0.2*
***Dodonaea* shrubland**	2	5.8±1.8	0.8±0.04	0.6±0.1	0.01±0	0.8±0.1	0.11±0.03	7.65±0.155
	2	*5.8+1.8*	*0.8+0.04*	*0.6+0.1*	*0.01+0*	*0.8+0.1*	*0.11+0.03*	*7.65+0.2*
***Maireana* shrubland**	17	7.5±1.2	2.3±0.3	1.1±0.1	0.3±0.1	0.6±0.02	0.11±0.01	6.59±0.299
	5	*8.8+1.3*	*2.5+0.7*	*1.3+0.2*	*0.4+0.2*	*0.7+0.04*	*0.13+0.01*	*7.4+0.27*
***Casuarina* woodland**	14	9.0±1.6	3.2±0.6	1.0±0.1	0.3±0.1	0.7±0.03	0.15±0.03	6.97±0.122
	5	*2.8+0.1*	*1.3+0.1*	*0.7+0.1*	*0.1+0.1*	*0.6+0.02*	*0.05+0.01*	*7.0+0.09*
***A. vesicaria* shrubland**	8	9.7±0.5	8.2±1.5	1.6±0.2	1.7±0.5	0.5±0.03	0.66±0.29	5.98±0.377
	4	*10.1+2.5*	*10.4+3.5*	*1.6+0.4*	*2.0+1.2*	*0.5+0.08*	*0.88+0.6*	*7.0+0.21*
Mallee - chenopod	14	11.2±2.3	2.5±0.3	0.8±0.1	0.1±0.03	0.7±0.03	0.11±0.02	6.94±0.244
	5	*7.0+2.1*	*1.4+0.3*	*0.5+0.1*	*0.1+0.1*	*0.7+0.04*	*0.09+0.03*	*7.04+0.3*
Black Box woodland	20	13.7±1.2	7.5±0.9	1.5±0.2	0.9±0.2	0.6±0.02	0.22±0.03	6.02±0.200
	5	*19.8+1.7*	*13.5+0.5*	*2.7+0.2*	*1.9+0.2*	*0.5+0.03*	*0.37+0.03*	*7.2+0.22*

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SHORT COMMUNICATION

New findings of the rare tree *Syzygium paniculatum* (Myrtaceae) in the Wyong area, New South Wales

Introduction

Syzygium paniculatum Gaern. (Brush Cherry or Magenta Lilly Pilly) has only been known from a few isolated localities along the New South Wales coastline between Jervis Bay and Myall Lakes (Hyland 1983). Collections from Bulahdelah, Gosford, Towra Point and St Georges Basin have been recorded (National Herbarium of NSW. It has been found in remnant littoral rainforests, generally in low population numbers.

The species is coded 3ECi by Briggs & Leigh (1988), indicating that it is inadequately conserved in national parks or nature reserves and is regarded as being endangered, with a serious risk of disappearing from the wild within one or two decades. This paper reports recently discovered populations in the Wyong area on the Central Coast and provides basic data on the vegetation and ecology which may contribute towards a management program for the species.

Locations

Following fieldwork in 1989, further populations have been identified (Figure 1). The first population (Site A) is to be found on the North Entrance Peninsula (151°31′10″E 33°18′30″S). It occurs as a narrow linear band along the slope of an east facing sand dune which was left undisturbed during previous sand mining operations. The population appears to number at least fifty trees on the eastern side of the main road with at least twenty trees thought to be present on the western side. The latter has not been field verified. They lie outside the littoral rainforest site No. 171a conserved by State Environment Planning Policy No. 26.

Site B is a small population adjacent to but outside the southern boundary of the Munmorah State Recreation Area (151°34′30″E 33°13′50″S). It lies at the base of a west facing sand dune. Further sporadically distributed individuals have been located around Lake Munmorah nearby.

Site C is along the banks of Ourimbah Creek and may possibly prove to be the largest population. At this stage at least forty trees have been located between the valley's upper and lower reaches (151°20′30″E 33°21′00″S - 151°16′30″E 33°18′30″S). Some trees are large, with one specimen having a diameter (dbh) of nearly 1 metre. Ourimbah Creek is sinuous and private property prohibits further investigation. The survey was confined to the point where Ourimbah Creek and Ourimbah Creek Valley Road meet. Thus, although the trees have been found all along the creek and on the flood plain downstream as far as the Pacific Highway, the full extent of the population remains unknown.

Habitat

Hyland (1983) states that the species is known from 'sandy soil or on stabilised sand dunes in coastal areas'. This description aptly describes their habitat in the Wyong area.

Site A on the North Entrance Peninsula is on Quaternary coastal sand dunes comprising deep medium grained quartz sands with shallow podsol development. Although recontouring of the dune system after sand mining has occurred immediately east of the populations location, they appear to occupy a mid slope position. As far as can be ascertained, because of infestation with *Lantana camara* and *Chrysanthemoides monilifera*, the population is in littoral rainforest. Associated species include *Ficus fraseri, Elaeocarpus obovatus, Acmena smithii* and *Rhodomyrtus psidioides.*

Site B is similar except that it is located at the base of a sand dune where ponded conditions can occur. Adjacent vegetation is remnant swamp forest of *Melaleuca quinquenervia.* At the time of the survey ponding of water 300 mm deep was present. *Eleocarpus obovatus* is co-dominant with an understorey of *Hypolepis muelleri.*

At site 6 the deep sands of the Quaternary Alluvium extend along the Ourimbah Creek Valley but are absent from adjacent gullies. *S. paniculatum* appears to be confined only to the main Ourimbah Creek where these sands occur and appears to be eliminated from the side gullies where the Terrigal Formation Shales outcrop (viz., Harden 1986, Payne 1987). Vegetation present along the Ourimbah Creek may be described as gallery rainforest dominated by *Cryptocarya glaucescens* and *Acmena smithii* which Floyd (1985) has described as belonging to the *Acmena-Doryphora* alliance.

Annual average rainfall for North Entrance is 1266 mm (at North Head) and at Ourimbah about 1300 mm.

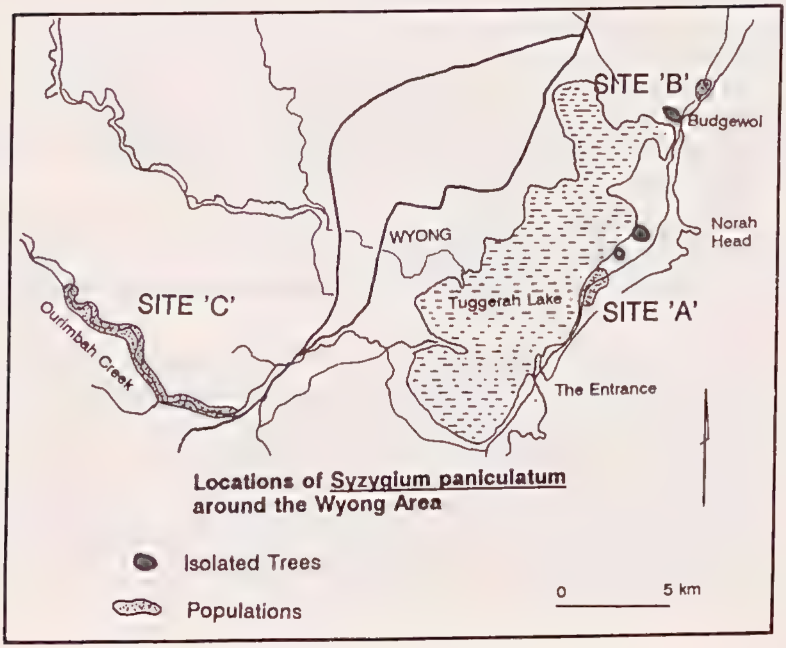

Figure 1. Location of populations of *Syzygium paniculatum.*

Ecology

It appears *Syzygium paniculatum* is able to tolerate both wet and dry conditions on sands. At Site B the presence of an understorey of *Hypolepis muelleri* and the presence of *Melaleuca quinquenervia* adjacent suggests permanent moisture. A flooding regime at Site C further suggests inundation is tolerated. Ourimbah Creek Valley is flooded several times each year.

Fire appears to be a regenerative mechanism. At Site A many trees have coppiced stems with the original main stem being burnt out. This response appears to be similar to *Acmena smithii* and *Backhousia myrtifolia*, though the effect of frequent fires is not known.

No information is available on the regenerative potential from seed. The population in the Ourimbah Creek Valley was revealed because the White-headed Pigeons (*Columba leucomela*) were feeding on the fruit. However there is little evidence of regenerating seedlings but cattle graze amongst the population. A heavy fruit was set in March 1990.

Conservation potential

Planning for the inclusion of the population at Site A into the Wyrrabalong National Park is underway. A decision by National Parks and Wildlife Service and the New South Wales Department of Lands is pending.

Site B has potential to be conserved within the Munmorah State Recreation Area for the population lies alongside the southern boundary. Site C has some potential for conservation as the population lies on both rural private property and Crown land.

Conclusions

Syzygium paniculatum in the Wyong area appears to be confined to Quaternary sands in rainforest but absent from the Terrigal Formation shales where gully rainforests occur. It appears to tolerate variable habitat conditions and resprouts after fire. Adequate protection of populations is needed if long-term conservation is to be assured.

Acknowledgments

I would like to thank my two colleagues, Andrew Sourry and Peter Clifford for helping with field work. Many thanks to Peter Wilson for verifying my findings and Doug Benson for editing the manuscript.

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Cunninghamia Vol. 2(3): 499–500

SHORT COMMUNICATION

Ecology of Sydney Plants Project

Conventional floras and handbooks provide descriptions for identifying species, but give relatively little ecological and biological data. Yet such data is becoming increasingly relevant to researchers in many fields and to natural area managers, who have the task of trying to predict the ecological consequences of management regimes, such as fire frequency, on native vegetation. Such data are also important for environmental impact assessment and for predicting the effects of changes in drainage, water movement, wind exposure or nutrient conditions on plant species and communities.

The Sydney region is interpreted broadly, being defined here as by Beadle, Evans and Carolin in the *Flora of the Sydney Region*. It thus covers the area bounded by Newcastle, Singleton, Rylstone, Taralga and Nowra. Information provided will be largely complementary to taxonomic descriptions, and will include growth form, flowering and fruiting times, longevity and maturity periods, pollination and seed dispersal data, distribution, habitat and plant community, and responses to fire and disturbance.

The project will be based at the New South Wales National Herbarium and will involve gathering material from published and unpublished sources as well as herbarium records and field observations. Much of the information is difficult to obtain because it is either scattered through a wide range of publications, both scientific and general, or simply not available in written form, but held in the capacious memories of field and herbarium botanists. Often indeed no-one has noted, for example, whether a species resprouts after fire, or how it is dispersed. Direct field observations will therefore supplement the review of literature. The emphasis in the first instance will be on providing information that is available, and the project will inevitably demonstrate a lack of knowledge about many plant species. Collaboration with other ecologists and botanists as well as with other interested people will be sought.

The types of information to be gathered are indicated below:

Growth form
Longevity
Growing season
Vegetative spread
Time to first flowering
Pollen vector
Time to first fruiting
Fruiting time
Time of seed dispersal
Seed production
Appendages on dispersal unit
Seed size
Seed weight
Seed longevity
Dormancy mechanism
Dispersal mechanism
Germination requirements
Interaction with other organisms
Distribution
Locations
Botanical subregions
Habitat
Typical abundance
Vegetation
Substrate
Soil nutrient
Soil drainage
Moisture supply
Soil salinity
Soil pH range
Shade
Exposure
Altitude
Annual rainfall
Response to fire
Seed bank
Conservation

We plan to proceed by the following steps:

•Literature review and preparation of draft listings that will be made available progressively to ecologists and botanists who can assist by filling gaps in the information. A database will be developed to record both data and the source from which each item has been obtained.

•Publication in *Cunninghamia* of the work in about ten parts, each covering about 250 species. If feasible, parts will be produced annually. Such publication will again assist in obtaining information from other sources, as well as making the data accessible as it becomes available.

Part 1 Ferns, Fern-allies, Cycads and Conifers

Part 2 Acanthaceae to Brassicaceae

Part 3 Cabombaceae to Eupomatiaceae

Part 4 Fabaceae

Part 5 Flacourtiaceae to Myrsinaceae

Part 6 Myrtaceae

Part 7 Nyctaginaceae to Rubiaceae

Part 8 Rutaceae to Zygophyllaceae

Parts 9 & 10 Monocotyledons

•Eventually a comprehensive publication covering all groups is planned. This will update the information given in the earlier publication of sections of the work.

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SHORT COMMUNICATION

Flowering times of plants found in Oxley Park, Tamworth. An addendum

Macrozamia

Following publication of my paper 'Flowering times of plants found in Oxley Park, Tamworth' (*Cunninghamia* 2(2): 197–216), Dr Lawrie Johnson (National Herbarium of NSW) informed me that the *Macrozamia* referred to in the table and the discussion was incorrectly identified. The species at Oxley Park is *Macrozamia stenomera* L. Johnson not *Macrozamia diplomera*. *M. stenomera* is listed by Briggs and Leigh (1988) as a rare species with a range of less than 100 km. It is conserved in Mount Kaputar National Park but no information is available on the adequacy of reservation. The species is recorded from as far north as Bingara and is now known from three collections from the Tamworth district (L. Johnson pers. comm.).

Aphanes

One other native species, *Aphanes australiana* (Rothm.) Rothm., a member of the family Rosaceae has been found in the Park since publication. This species flowers in September and October. Although first noted late in 1990, the plant is locally common and was probably overlooked in the past because of its small size.

Reference

Briggs, J.D. & Leigh, J.H. (1988) *Rare or threatened Australian plants*, Special Publication No. 14 (Australian National Parks & Wildlife Service: Canberra).

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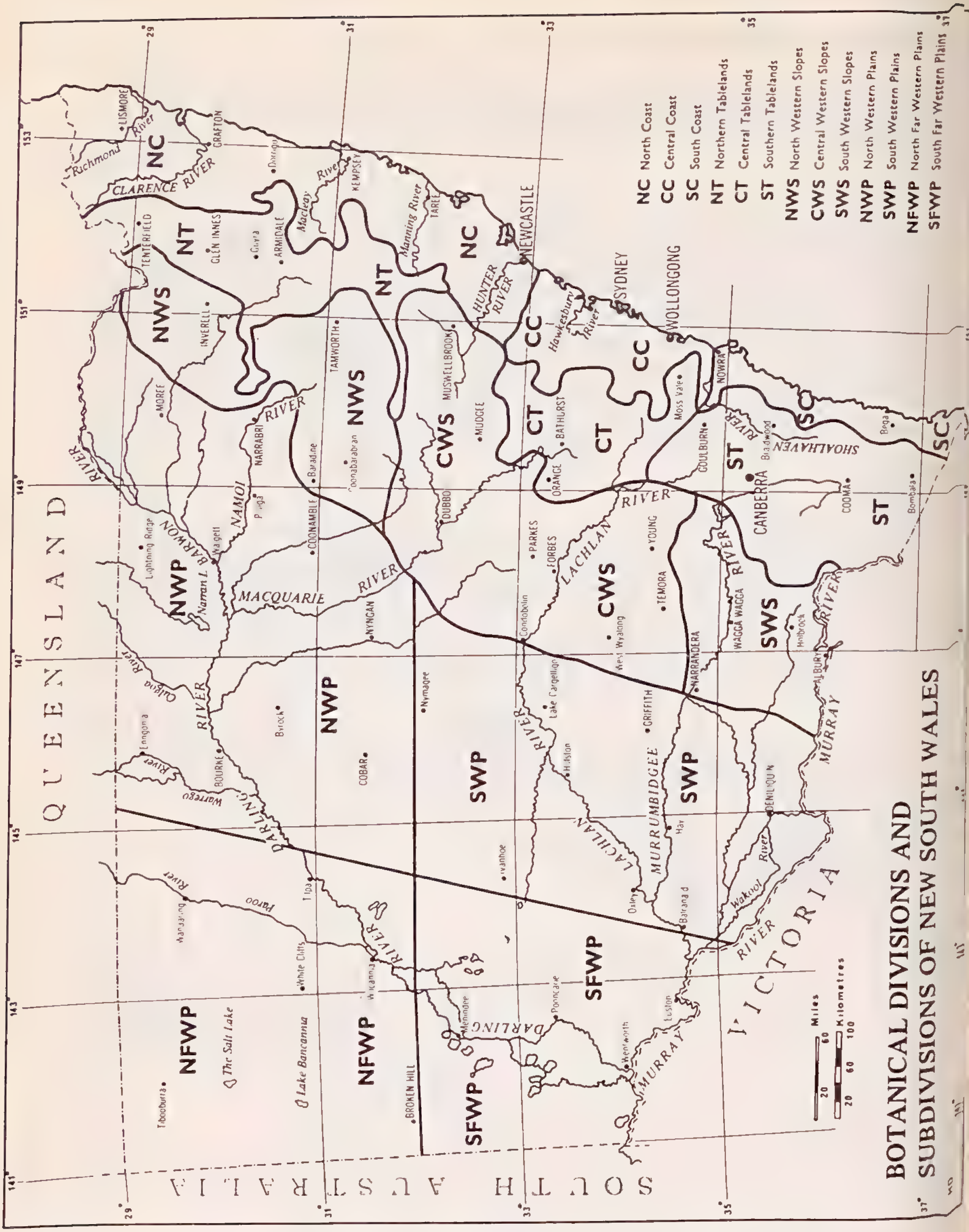

For explanation and description of the Botanical Divisions and Subdivisions of New South Wales see Anderson, R. H. (1961). Introduction. *Contr. New South Wales Natl. Herb. Fl. New South Wales* Nos 1–18, pp. 1–15.

The distribution, abundance and conservation status of *Grevillea beadleana* (Proteaceae): an endangered species

J.S. Benson

Abstract

Benson, J.S. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1992. The distribution, abundance and conservation status of Grevillea beadleana: *an endangered species.* Cunninghamia 2(4): *503–521.* The two known disjunct occurrences of *Grevillea beadleana* (Guy Fawkes Lat. 30° 07´ S Long. 152° 19´ E and Binghi Lat. 29° 12´ S Long. 151° 45´ E) on the Northern Tablelands of NSW are documented for their population structure, edaphic features and associated plant species. *Grevillea beadleana* grows on granitic substrates with >75% silica content; derived soils are low in Mg, Ca, P and N. The abundance in three size classes at both populations (classified as seedling, young adult and mature adult) reflect recent fire history and subsequent recruitment. Seedling growth is highly susceptible to repeated fire and the species may have become rare due to increases in fire frequency over recent times. Death due to water stress during droughts may also limit numbers. Future research should centre on seed production, storage, viability and germination. This will refine management objectives regarding the optimal fire intensity and frequency for maintaining viable populations. In the interim, fire should be excluded from recently burnt areas for at least 15 years. Reservation (or protecting by other means) of the land on which the largest population occurs, at Oaky Creek Binghi, is necessary for the adequate conservation of the species.

Introduction

Grevillea beadleana McGillivray (family Proteaceae) is an attractive reddish-flowered shrub, growing on granitic outcrops in two locations on the Northern Tablelands of New South Wales. It was first collected in 1897 by Captain Crawford of 'Moona Plains' 30 km east of Walcha but searches of the granitic outcrops in this area, where it is presumed to have been first collected by Captain Crawford, have so far failed to re-locate the species (R. Makinson, pers. comm.). In 1981 it was rediscovered by N. Fenton (and collected in the same year by A.G. Floyd) on the rim of the eastern side of the Guy Fawkes River gorge inside Guy Fawkes River National Park. In 1988, another population was discovered by G. Roberts in the eastern section of the Binghi wilderness region, north of Torrington. The Guy Fawkes and Binghi populations are 115 km apart, separated by the Guy Fawkes River gorge system and the high altitude section of the New England Tableland between Glen Innes and Tenterfield, (Figure 1).

Grevillea beadleana is assigned a conservation status code of 2RC- in the Australian rare or threatened plant list (Briggs and Leigh, 1988). This has since been altered and its current threat rating is 3ECi (J. Briggs pers. comm.). The 3 implies the species extends over a range exceeding 100 km; E implies it is considered to be endangered with a serious risk of becoming extinct over the next few decades and Ci implies that it has less than 1 000 individuals in conservation reserves.

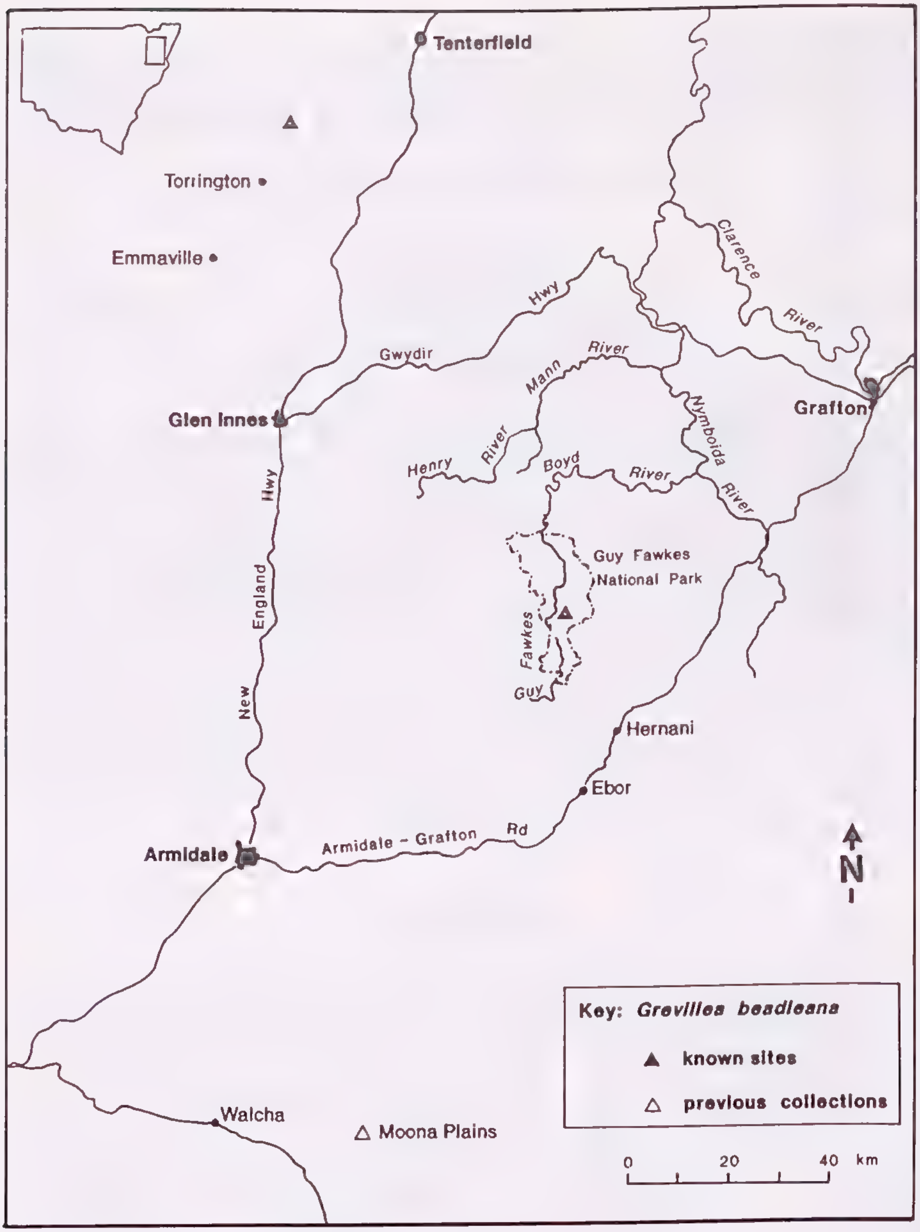

Figure 1. Recorded locations of *Grevillea beadleana*

Research of *Grevillea beadleana* has been limited to a field survey documenting its distribution, population size (including size classes as of 1991) and habitat (including associated plant species, soil and substrate).

While demographic studies are lacking, field survey data provide a basis for hypotheses about the causes of the species' rarity and current distribution.

Limited cultivation of the species has taken place at the Royal Botanic Gardens, Coffs Harbour Botanic Garden and a few private nurseries.

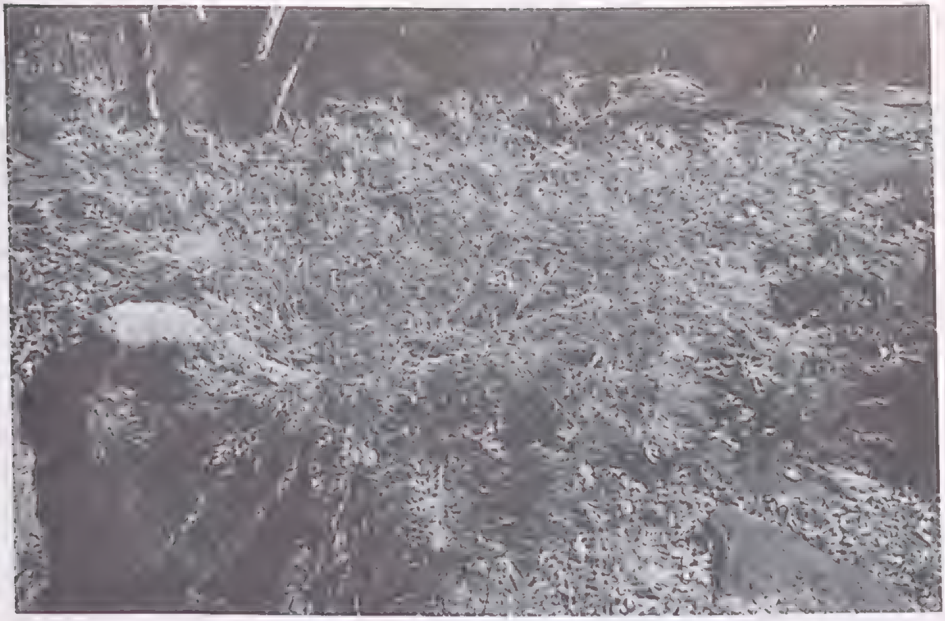

Figure 2. *Grevillea beadleana* is a robust shrub up to 2m high. The largest known population occurs along Oaky Creek, north of Torrington, on the western side of the Northern Tablelands.

Taxonomy

Grevillea beadleana is a spreading shrub up to 2 m high with divided, lobed, tomentose leaves 8–16 cm long and 5–10 cm wide (Figure 2). The reddish-purple flowers are aggregated in an erect 'toothbrush'-like terminal inflorescence (Figure 3). Flowering mainly occurs in late spring or summer but continues into early winter. The two-seeded fruits (follicles) are 10 mm x 6 mm coloured with brown to purple, longitudinal stripes. The seeds are about 5 mm long.

The first publication of the name *Grevillea beadleana* was in McGillivray (1986). This contains a minimal diagnosis. It is also described in Harden (1991). A full description of the species is included in a current revision of the genus *Grevillea* (McGillivray, in press).

McGillivray (in press) notes that the original collection from near Walcha in 1897 has broader and more sparingly divided primary leaf-lobes compared to the leaves of material collected at other sites but he still places it within the species *beadleana*.

Grevillea beadleana is placed in the 'toothbrush inflorescence' group of the genus Grevillea. Other related species in this group include *Grevillea willisii*, *G. caleyi* and *G. longifolia*, each of which is also listed as rare or threatened (Briggs & Leigh 1988).

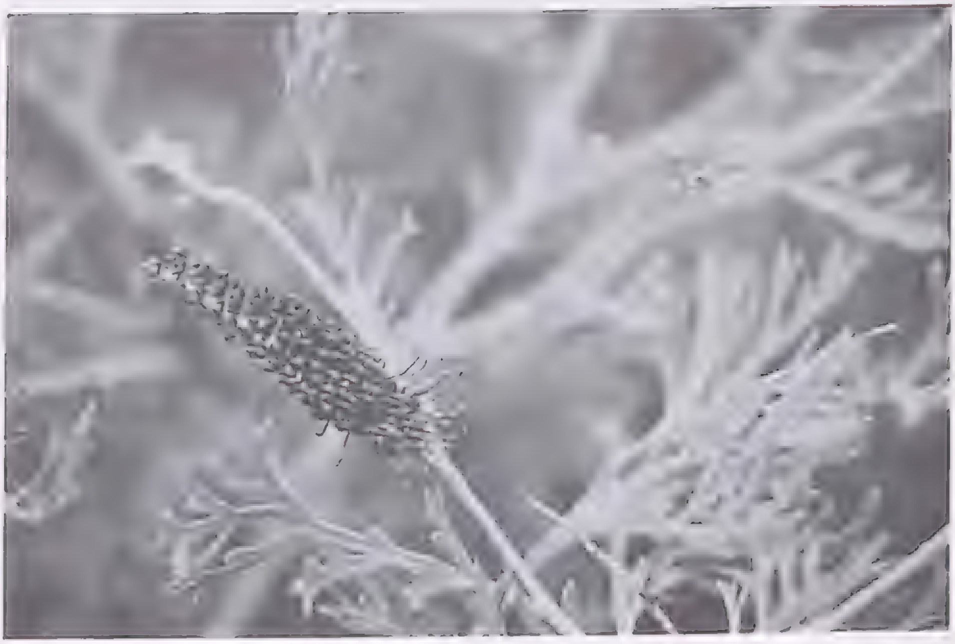

Figure 3. *Grevillea beadleana* mainly flowers in late spring and summer. It is placed in the 'toothbrush inflorescence' group of its genus.

Table 1. Herbarium collections of *Grevillea beadleana*..

Collector	**Coll. No.**	**Lat./Long.**		**Place**	**Date**	**F**
Capt. Crawford	Mel 75263			Moona Plains	1887	
A.G Floyd	AGF 1774			Guy Fawkes	15/10/1981	Y
J.B. Williams	NSW 151305	30° 00′ S	152° 20′ E	Guy Fawkes	13/06/1982	Y*
D.J. McGillivray	DJM 3993	30° 05′ S	152° 19′ E	Guy Fawkes	06/09/1982	Y
J.B. Williams	NE 48771A	30° 07′ S	152° 19′ E	Guy Fawkes	26/06/1988	
J.S. Benson	NSW 26879	29° 13′ S	151° 45′ E	Eastern Binghi	25/04/1989	Y

MEL - National Herbarium, Melbourne
NSW - National Herbarium, Sydney
NE - Herbarium of the University of New England
AGF, DJM - Personal collection number
F - specimen flowering
* - type collection

Methods

Using locality information from herbarium collections (Table 1), the known occurrences of *Grevillea beadleana* were visited. Nearby likely locations, chosen on the basis of aerial photographic interpretation and mapped geology, were also searched. These included Guy Fawkes Crags, 8 km north of the known location on the rim of the Guy Fawkes Gorge, and several granite knolls in the vicinity of Oaky Creek near Binghi. Floristic site data collected in the vicinity of Oaky Creek (Williams 1990) were reviewed.

The Binghi population occurs in two topographically distinct places - along Oaky Creek and on an unnamed knoll about 1 km to the west of the Creek. These subsets of the one population were sampled in April 1989 for associate species with six 20 x 20 m quadrats (five quadrats along the Creek and one on the knoll). During a second visit to the area in July 1991 the number of individuals of *Grevillea beadleana* on the knoll was counted, while estimates of the larger population along Oaky Creek were made using counts of the species in three 20 x 20 m quadrats. A count of the Guy Fawkes population was also made in July 1991.

Population counts were divided into three size classes with the view that these may have reflected several different aged cohorts arising from different germination events. Such events were most likely stimulated by fire but they could also have arisen during favourable climatic conditions. The size classes were: up to 40 cm (seedling), 40–80 cm (young adult) and greater than 80 cm high (mature seed-bearing adult). Other plant species in the quadrats were listed and assigned a cover rating using a modified Braun-Blanquet method.

Ten randomly collected sub-surface soil samples were taken from each of the populations at Guy Fawkes and Binghi (Oaky Creek). The samples from each site were mixed to gain an average sample for each site. This was tested for pH, electrical conductivity (EC), exchangeable cations of the elements calcium (Ca), magnesium (Mg) potassium (K), sodium (Na); nitrogen (N), sulphate (S), iron (Fe) and for exchangeable aluminium (Al) and phosphorus (P). Samples of rocks from the Guy Fawkes and Binghi sites were analysed for their mineralogy and major elements.

Measurements of slope, aspect and altitude were made at each site. Rainfall data from nearby stations were obtained from the Bureau of Meteorology.

Results

Grevillea beadleana is known from only two locations - Guy Fawkes and Binghi (Table 2). These two disjunct populations are described below.

Guy Fawkes

This occurrence is situated 45 km north of the town of Ebor, 3 km south-west of Chaelundi Mountain and 4 km south of Chaelundi Falls (Lat. 30° 05´ S Long. 152° 19´ E, altitude 950 m). It is accessible from the township of Hernani off the Grafton-Armidale Road via Marengo, Hardens and Misty Creek Roads.

The stand of *Grevillea beadleana* extends over an area of approximately 300 x 100 m (3 ha) downslope from the Escarpment Walking Track inside Guy Fawkes River National Park. Its habitat is a steeply sloping granitic bluff (Figure 4). The top section of the bluff adjoins an undulating plateau containing tableland species such as *Eucalyptus caliginosa* (New England Stringybark); the lower section contains some coastal plants, for example *Eucalyptus maculata* (Spotted Gum). Very few individuals of *Grevillea beadleana* survive away from the rock outcrop, either upslope or downslope.

Population

A total of 266 plants of *Grevillea beadleana* were counted at this location in July 1991. Nearly half of the individuals were seedlings. These grew over an area where adult plants had been burnt and killed in 1988. There was a dominance of mature adults in the unburnt section of the site. This partial burning of the site led to the overall population at the site being evenly divided between mature adults and seedlings (Table 3). Few young adults were recorded.

It was observed that many seedlings had established downslope from adult plants killed in the recent fire. The average height of these post fire seedlings was 20 cm. Sections of the cliff that were not burnt contained a small number of seedlings which may indicate there is limited germination in the absence of fire.

Substrate and soil

The outcropping granitic rock forming the bluff is silica-rich (>75%) leucocratic, feldspathic granite (R. Barnes, Geological Survey, Armidale, pers. comm.). This rock is part of a complex of granitic outcrops mapped as the Chaelundi Granite that outcrops over most of the plateau and gorge rim in the Chaelundi Mountain area. Its chemical constituency is dominated by silica and aluminium (Table 4). Minuscule levels of phosphorous and magnesium are present in the substrate.

The sandy-loam, skeletal soil derived from this highly siliceous substrate is poor in nutrients typified by a very low calcium and magnesium content. It also contains low levels of phosphorus and nitrate. In contrast, high levels of aluminium and iron are present due to the acidic pH and base unsaturates (Table 5).

Rainfall

Based on data collected at the nearby 'Marengo' homestead on the eastern side of the gorge (853 m, data recorded 1964–1976) and the 'Ponderosa' homestead on the drier, western side of the gorge (data recorded 1964–1974), the annual rainfall is estimated

Table 2. Location, altitude, aspect, slope, geology, soil, landform and tenure of *Grevillea beadleana* locations

Location	Lat/Long	Alt(m)	Asp.	Slope	Geology	Soil	L/form	Tenure
Guy Fawkes	30° 05′ 152° 19′	950	290	40	Chaelundi granite	sand	upper slope	Nat. Park
Binghi Oaky Ck	29° 12′ 151° 45′*	650	0	10	Mole Ck granite	fine sand	creek bank**	Crown lease
Binghi knoll	29° 13′ 151° 44′	840	270	15	Mole Ck granite	sand	hilltop +slope	Crown lease

* The lat/long along Oaky Creek is set in the middle of this population which extends for 1.5 km.

** *Grevillea beadleana* mainly occurs on the eastern (westward facing) side of Oaky Creek.

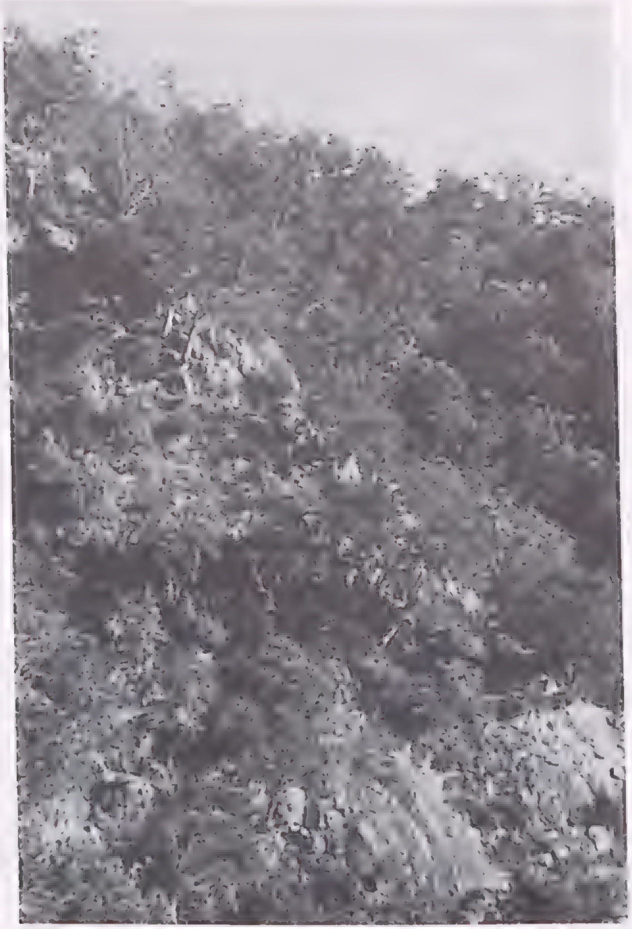

Figure 4. Protected from fire by its position on a granitic bluff, 266 plants of *Grevillea beadleana* were counted in 1991 on this granitic bluff on the rim of the Guy Fawkes River gorge inside Guy Fawkes River National Park. This is the only known conserved population.

to be approximately 1 000 mm (Figure 5). The rainfall is seasonal with three times as much falling in summer (November to February) than winter. Minimum rainfall is recorded in April, May and September.

Associated vegetation

Due to the predominance of rock outcrop the vegetation is woodland with a sparse shrub understorey. In the upper stratum *Eucalyptus campanulata* and the rare *Eucalyptus michaeliana* dominate with occasional small specimens of *Lophostemon confertus.* The middle stratum is dominated *Leptospermum novae-angliae, Allocasuarina littoralis, Grevillea beadleana* and *Notelaea microcarpa.* Scattered clumps of grasses, herbs and sedges make up the ground stratum with the most common plant species being *Gonocarpus teucrioides, Lepidosperma laterale, Poa sieberiana, Stipa ramosissma, Pomax umbellata* and a species of *Aristida.* A list of plant species recorded from the site is included in Table 6.

Table 3: Number of plants in size classes for *Grevillea beadleana* at its known locations (July 1991).

Location	Area (ha)	Population (% in brackets)			Dead*	Total alive
		<40 cm	40–80cm	>80cm		
Guy Fawkes	3	127(48)	48(18)	91(34)**	NA	266
Binghi* Oaky Creek	15	67(2)	183(5)	3 410(93)	458	3 660
Binghi knoll	5	182(57)	25(8)	113(35)**	NA	320
Totals	23	376(9)	256(6)	3 614(85)		4 246

The Oaky Creek population was estimated from counts in three quadrats. Guy Fawkes and Binghi knoll populations were counted.

* dead plants from non-fire sources: only estimated for the Oaky Creek population.

** half of the population at these sites was burnt in 1988.

NA not assessed

Table 4. Major elements in rock samples

Element	Guy Fawkes (%)	Binghi (%)
SiO_2	77.40	76.60
TiO_2	.10	.13
Al_2O_3	13.15	12.65
Fe_2O_3	.17	1.33
MnO	.01	.03
MgO	.03	.08
CaO	.22	.13
Na_2O	4.00	3.25
K_2O	4.31	4.95
P_2O_{03}	.02	.03
S	.00	.00
LOI	.48	.40
Total	99.89	99.58

Table 5. Properties of surface soil samples (0-10 cm)

Location	Soil properties										
	pH	Salinity (mS/cm)	Exchangeable cations				Ex Al*	Fe	S	N as (Nitrate)	P
			Na	K	Ca	Mg					
Guy Fawkes	4.0	0.06	35	172	244	118	45%	107	78	0.9	5.0
Binghi	4.3	0.04	21	138	506	96	25%	66	58	0.3	2.0

Exchangeable cations and other elements expressed in ppm with the exception of exchangeable aluminium (Ex Al) which is given as a percentage of exchangeable cations.

pH is based on soil suspension in CaCl^2 solution.

Land-use history

Guy Fawkes River National Park was gazetted in 1972. Beforehand the area was vacant Crown land with licensed occupancies for grazing. Some of the forest above the gorge rim has been cleared in the past and has re-grown. The site where *Grevillea beadleana* occurs would have changed little since European settlement. It is included in an area that has been nominated as wilderness under the Wilderness Act 1987.

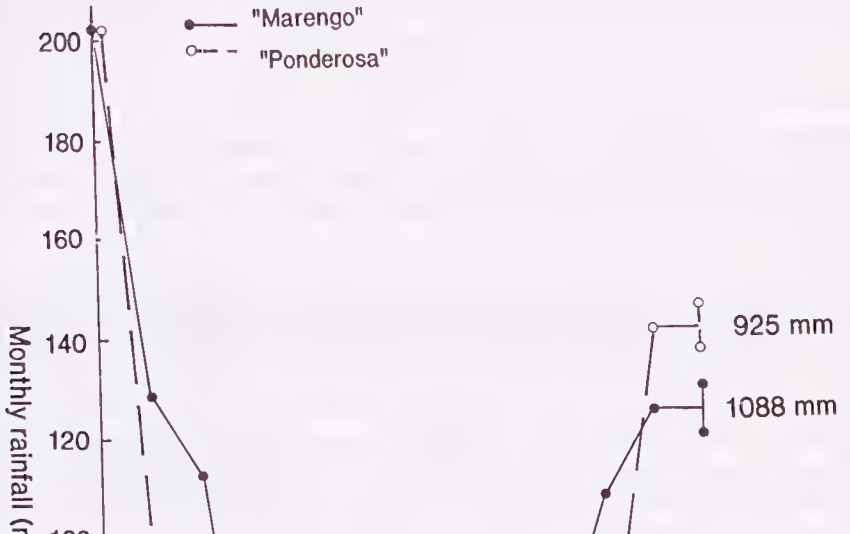

Figure 5. Mean rainfall for two stations in the vicinity of Guy Fawkes. Data supplied by the Bureau of Meteorology (1991).

Binghi

The Binghi population is distributed along a 1.5 km section of Oaky Creek (Lat. 29° 12´ S, Long. 151° 45´ E, altitude 950 m) and on a rocky knoll, 1 km to the west of Oaky Creek.

Unlike the situation at Guy Fawkes, where a steep bluff forms the habitat, the Binghi population occurs on undulating terrain, although there are some steep slopes adjoining the creek and the knoll. Most of the plants grow on a narrow strip of land within 100 metres of Oaky Creek. More plants are present on the eastern bank than the western bank. *Grevillea beadleana* grows on skeletal soil in crevices between granite outcrops which dominate the landscape.

Population

In July 1991, the population of *Grevillea beadleana* at Binghi was estimated to be approximately 4 000. Of this, 3 650 individuals were estimated to be distributed over 15 ha along Oaky Creek (Table 3) and 320 were counted over 5 ha on the knoll west of Oaky Creek.

The two subpopulations at Binghi have markedly different size class structures. More than half of the area of *Grevillea beadleana* on the knoll was burnt by a hot fire in 1988. This fire missed most of the plants along Oaky Creek. As a consequence, 57% of plants on the knoll were seedlings (Figure 7), in contrast with just 2% of the plants along the Creek. The Creek population is dominated by mature adults (93%).

Although there is no apparent physiographic difference between the creek banks of Oaky Creek, more plants were found on the eastern side compared to the western side. This distribution may be explained by the origin of fires in the west, possibly eliminating plants burnt before they could mature and set seed (see discussion below).

The two subpopulations at Binghi are growing in quite different topographical situations although they are only 500 m apart. It is possible that these subpopulations were once contiguous.

Despite searches of other knolls and creeks in the area by the author and others (Williams 1991) no other populations of *Grevillea beadleana* have so far been discovered.

Estimates taken for the Oaky Creek Binghi population reveal that 9% of the mature plants had died as a result of a drought in the early part of 1991. Many other individuals appeared to be suffering from water stress, indicating that this factor may be important in driving population fluctuations.

Substrate and soil

Mole Creek Granite is the major rock type in the area covering 40 000 ha. This granite is similar in its composition to the rock type at Guy Fawkes in having a >75% silica content, high aluminium levels and low levels of other elements (Table 4). However, it is relatively fine-grained compared with the Guy Fawkes granite and yields a fine loamy-sand soil. The soil is poor in nutrients illustrated by its low level of basic exchangeable cations - calcium and magnesium. Also, it is acidic, low in salts, nitrate and phosphorus but has a high exchangeable aluminium component (Table 5).

On flatter terrain away from the Creek, drainage is poor. The water table rises quickly to the surface after rain causing boggy conditions. *Grevillea beadleana* was rare here.

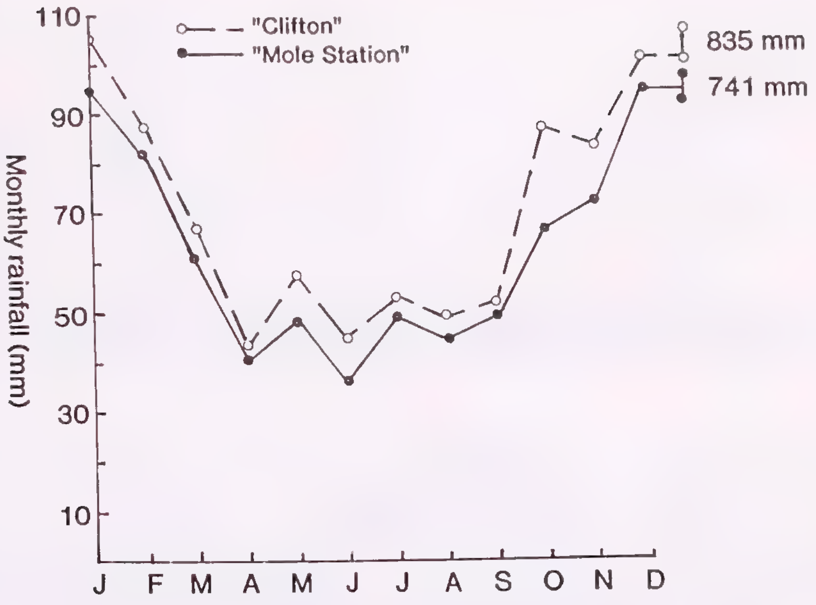

Figure 6. Mean rainfall for two stations in the vicinity of Oaky Creek, Binghi. Data supplied by the Bureau of Meteorology (1991).

Rainfall

Based on rainfall data recorded from nearby properties (Figure 6) the estimated annual rainfall in the Oaky Creek section of Binghi is approximately 800 mm (Bureau of Meteorology, 1991). 'Clifton' is located 20 km north of Oaky Creek at a similar altitude (670 m) (data recorded 1948–1990). 'Mole Station' is 10 km north of Oaky Creek at a lower elevation (440 m) (data recorded 1950–1990). The area is substantially drier than the Guy Fawkes site and probably has a higher evaporation rate due to higher average temperatures experienced at this lower altitude.

Associated vegetation

Vegetation structure is predominantly open-forest except along creek beds or on rock platforms where shrubs and forbs dominate. Common overstorey trees along Oaky Creek are *Eucalyptus prava, E. andrewsii, E. stannicola, Callitris enlicheri* and *Angophora floribunda*. On the knoll west of Oaky Creek *Eucalyptus andrewsii* is the dominant tree.

There is a diverse understorey flora with common shrub species including *Acacia granitica, Baeckea densifolia, Leptospermum brachyandrum, L. brevipes, Notelaea linearis, Mirbelia speciosa, Persoonia terminalis* subsp. *terminalis* and *Phebalium squamulosum*. Grasses, tussock forbs and sedges form a mid-dense ground cover. Common species include *Schoenus ericetorum, Xanthorrhoea glauca, Lepyrodia leptocaulis, Lomandra longifolia, Aristida armata, Cymbopogon obtectus* and *Eragrostis brownii*.

A combined plant species list from the *Grevillea beadleana* sites along Oaky Creek and on the adjacent knoll is given in Table 6.

Table 6. Plant species associated with *Grevillea beadleana.*

Species	Family	L	B	GF
Acacia sp. aff. *falciformis*	Fab.	S	1	
Acacia fimbriata	Fab.	S	1	
Acacia granitica	Fab.	S	2	
Acacia penninervis	Fab.	S	1	
Acacia pruinosa	Fab.	S	1	
#*Acacia torringtonensis*	Fab.	S	2	
Acacia viscidula	Fab.	S	1	
Adiantum aethiopicum	Adiant.	E	1	
Allocasuarina littoralis	Casuarin.	S	2	4
Alyxia ruscifolia	Apocyn.	S		2
Aotus subglauca	Fab.	S	1	
Angophora floribunda	Myrt.	T	3	
Aristida armata	Po.	G	3	
Aristida sp.	Po.	G		4
Arundinella nepalensis	Po.	G	2	
Astrotricha longifolia	Arali.	S	1	
Billardiera scandens	Pittospor.	C		1
Banksia integrifolia	Prote.	T		1
Baeckea densifolia	Myrt.	S	3	
Boronia anethifolia	Rut.	S		2
Brachycome tenuiscapa var. *pubescens*	Aster.	F	2	
Brachycome stuartii	Aster.	F	1	
Brachyloma daphnoides	Epacrid.	S	1	
Breynia oblongifolia	Euphorbi.	S		1
Callistemon sp. aff. *pallidis*	Myrt.	S	1	
Callitris endlicheri	Cupress.	T	3	
Calotis dentex	Aster.	F	1	
Cassinia quinquefaria	Aster.	S	2	
Cassytha glabella	Laur.	C	1	
Cheilanthes sieberi	Adiant.	E	2	2
Correa reflexa	Rut.	S	1	
Crassula pedicellosa	Crassul.	F	1	2
Cryptandra scortechinii	Rhamn.	S	1	
Desmodium varians	Fab.	C		1
Dianella caerulea	Dianell	F		2
Hibbertia acicularis	Dilleni.	S	1	2
Hibbertia obtusifolia	Dilleni.	S		3
#*Hibbertia* sp. aff. *obtusifolia*	Dilleni.	S	2	
Hibbertia riparia	Dilleni.	S	1	
Hovea longifolia	Fab.	S	1	
Hybanthus filiformis	Viol.	F	1	
Hypoxus hygrometrica	Hypox.	F	2	
Imperata cylindrica	Po.	G	2	
Isopogon petiolaris	Prote.	S	1	
Isotoma anethifolia	Lobeli.	F	1	
Jacksonia scoparia	Fab.	S	1	3
Lepidosperma laterale	Cyper.	G	1	4
Leptospermum arachnoides	Myrt.	S	1	
Leptospermum attenuatum	Myrt.	S	1	
Leptospermum brachyandrum	Myrt.	S	3	
Leptospermum brevipes	Myrt.	S	4	
Leptospermum novae-angliae	Myrt.	S		4
Leptospermum polygalifolium	Myrt.	S	2	
Lepyrodia leptocaulis	Restion.	G	2	
Leucopogon attenuatus	Epacrid.	S	1	
Leucopogon lanceolatus	Epacrid.	S		1
Leucopogon muticus	Epacrid.	S	2	
Liparis reflexa	Orchid.	F		2
Lobelia dentata	Lobeli.	F	1	
Logania albiflora	Logani.	S	1	
Lomandra confertifolia subsp. *pallida*	Xanthorrhoe.	TF	1	
Lomandra longifolia	Xanthorrhoe.	TF	2	3
Lomatia sialifolia	Prote.	S	1	
Lophostemon confertus	Myrt.	T		3
Maytenus silvestris	Celastra.	S		1
Melichrus urceolatus	Epacrid.	S	2	3
Mirbelia speciosa	Fab.	S	2	
Micrantheum hexandraum	Euphorb.	S	1	
Notelaea linearis	Ole.	S	2	
Notelaea microcarpa	Ole.	S	1	3
Olearia ramosissima	Aster.	S	1	

Species	Family	L	B	GF
Dianella laevis	Dianell.	F	1	
Cymbopogon obtectus	Po.	G	2	
Cymbopogon refractus	Po.	G	1	3
Davallia pyxidata	Davalli.	F		2
Daviesia umbellifera	Fab.	S	1	
Dendrobium speciosum var. *hilli*	Orchid.	F		1
Dodonaea viscosa	Sapind.	S	1	
Entolasia stricta	Po.	G	3	3
Eragrostis brownii	Po.	G	3	
Eucalyptus andrewsii	Myrt.	T	2	
Eucalyptus bridgesiana	Myrt.	T	1	
Eucalyptus campanulata	Myrt.	T		5
Eucalyptus caleyi	Myrt.	T	1	
Eucalyptus dealbata	Myrt.	T	3	
#Eucalyptus michaeliana	Myrt.	T		4
Eucalyptus microcorys	Myrt.	T		2
Eucalyptus moluccana	Myrt.	T	1	
Eucalyptus prava	Myrt.	T	3	
Eucalyptus stannicola	Myrt.	T	4	
Exocarpus cupressiformis	Santal.	S		2
Ficus rubiginosa	Mor.	T	1	1
Geranium neglectum	Gerani.	F	2	
Gahnia aspera	Cyper.	G	1	
Glycine clandestina	Fab.	C	1	
Goodenia hederacea	Goodenia.	F	1	
Goodenia rotundifolia	Goodeni.	F	1	
Gonocarpus teucrioides	Halorag.	F	2	4
#Grevillea beadleana	Prote.	S	4	4
Grevillea linearifolia	Prote.	S	2	
Hardenbergia violacea	Fab.	C		2
Olearia viscosa	Aster.	S		1
Opercularia hispida	Rubi.	F	1	1
Patersonia sericea	Irid.	F	1	
Petrophile canescens	Prote.	S	1	
#Persoonia terminalis subsp. *terminalis*	Prote.	S	2	
Persoonia sp. aff. *sericea*	Prote.	S		1
Phebalium squamulosum	Rut.	S	2	
Pimelea pauciflora	Thymelae.	S	1	
Plectranthus graveolens	Lami.	F		2
Poa sieberiana	Po.	G		3
Polyscias sambucifolia	Arali.	S		2
Pomax umbellata	Api.	F	1	3
Pomaderris lanigera	Rhamn.	S	1	1
Pomaderris prunifolia	Rhamn.	S	1	
#Prostanthera staurophylla	Lami.	S	1	
Ptilanthelium deustum	Cyper.	G	2	
Pultenaea foliosa	Fab.	S	1	
Pyrrosia confluens	Polypodi.	F		2
Solanum cinereum	Solan.	S	1	
Schoenus ericetorum	Cyper.	G	2	
Stackhousia muricata	Stackhousi.	F	1	
Stipa ramosissima	Po.	G		3
Stylidium larcifolium	Stylidi.	F	1	2
Themeda australis	Po.	G		3
Trema aspera	Ulm.	S		1
Wahlenbergia stricta	Campanul.	F	1	
Xanthorrhoea glauca	Xanthorrhoe.	TF	2	2
Xyris gracilis	Xyrid.	G	1	
Zieria cytisoides	Rut.	S	1	

KEY

B = Oaky Creek, Binghi including the knoll west of the creek (average cover rating from six 20 x 20 quadrats).

GF = Guy Fawkes National Park - Chaelundi; cover rating assigned to species over the area of distribution of *Grevillea beadleana* i.e 300 m x 100 m.

L (life-form): T = tree; S = shrub; F = forb; TF =tussock; F = forb; E = fern; C = climber.

# rare or threatened on national or regional basis.

Cover ratings: 1 = <1%; 2 = 1–5%; 3 = 5–25%; 4 = 25–50% 5 = 50–75%; 6 = 75–100%.

Land-use history

Oaky Creek lies on the western side of the largest, naturally vegetated region on the Northern Tablelands of New South Wales - known as Binghi. The land tenure of the Binghi area is mainly Crown land and Crown lease and the main land uses are tin mining and rough grazing. It is one of the few areas on the western fall of the Great Dividing Range to have been classified as wilderness (Helman *et al.* 1976). Since the mid-1970s various proposals have been put forward to protect the natural features in the area. These have included establishing a national park, listing the area on the National Estate Register and declaring it as Wilderness (National Parks and Wildlife Service pers. comm., Australian Heritage Commission pers. comm, National Parks Association of NSW, 1976). The most recent report by the Department of Lands (1991) recommends that most of the Crown land in the Binghi area should be kept in Crown ownership and managed with the primary objective of maintaining its natural features. Such action would help prevent further clearing of native vegetation which is major threat to flora (including *Grevillea beadleana*).

Some abandoned tin mines are present in the area and there are traces of an old track running next to Oaky Creek - presumably related to mining earlier this century. Due to the rough topography, poor soils and the limited suitability of the vegetation as feed, grazing has been light.

Population biology

Field observations suggest that plants of *Grevillea beadleana* are usually killed outright when burnt. Lignotubers or similar root structures are absent and regeneration relies on the successful germination of seed and survival of seedlings. In a small number of cases, where the lower trunk has been protected from fire by rocks, suckering from the base of the trunk has been observed. It seems that given sufficent seed store the species will germinate well in the post-fire environment. There are no apparent limitations to pollination, although pollination vectors and mechanisms have not been studied.

Observations suggest that fruit do not persist on the plant but drop to the ground at maturity releasing their seeds. Large quantities of seed seem to be produced in both populations. The relatively heavy seed is unlikely to be dispersed far from its source.

The longevity of individual plants of *Grevillea beadleana* is unknown. A large specimen that was observed in 1981 at Guy Fawkes (J.B. Williams pers. comm.) was still alive in 1991 and must be at least 20 years old. It is likely that, left unburnt, individual specimens of *Grevillea beadleana* could live for several decades. In cultivation at Coffs Harbour Botanic Gardens plants grow quickly, flower in a year and produce viable seed within a maximum of three years (A. Floyd pers. comm.). Seeds remain viable in the soil for at least one year based on the time it took seedlings to emerge after the death of the only adult plant in the Coffs Harbour Botanic Gardens. This plant died after a prolonged wet period due to a fungal root infection (an incident that supports the view that *Grevillea beadleana* prefers better drained sites).

Care should be taken in extrapolating the Coffs Harbour observations to wild populations on the cooler tablelands where the growing season is shorter and habitat harsher than the coast. In its natural habitat the average height of seedlings two years after a fire was approximately 20 cm. From these observations it is estimated that, in its natural habitat, *Grevillea beadleana* may take up to five years to flower and seed.

Discussion

Along with many species in its genus, *Grevillea beadleana* favours well drained, acidic, low-nutrient soils - low in phosphorus, nitrate, calcium and magnesium but rich in silica and aluminium. Rainfall ranges from 800 mm to 1000 mm, altitudes from 950 to 650 m and aspect tends to be west to north-west.

The data confirm that *Grevillea beadleana* is a very restricted species. It also seems that given the limited number of collections, it was a restricted species at the time of European settlement. This supposition is based on a view that it is a highly attractive and distinctive plant - one which would not be easily overlooked by early collectors if it were widespread.

Though there is a potential large habitat for *Grevillea beadleana* in the Binghi area, recent botanical surveys covering lands around Torrington (Williams 1991) have failed to record it.

The rarity of *Grevillea beadleana* may be explained by historic and extant factors including changes in climate and detrimental fire regimes. From the historical perspective, *Grevillea beadleana* could now be surviving in climatic refugia. It may have been eliminated from other sites by extensive changes in climate over a long period of time and consequent competition with more adaptable species. This is supported by the fact that *Grevillea beadleana*, along with the also rare *Grevillea scortechinii*, are at the northern-most range of the *caleyi-longifolia-aspleniifolia* section of the 'toothbrush-inflorescence' group. Since there are related species in Western Australia it is possible that species in this group may have radiated from an ancient ancestor that lived perhaps as far back as 20–30 million years ago (R. Makinson pers. comm.). Also supporting this hypothesis is the apparent susceptibility of *Grevillea beadleana* to death from water stress during drought - a factor that may have eliminated the species from drier sites in the past.

If there has been a marked increased fire frequency in Australia (Singh *et al.* 1981) since human occupation, this may have had some impact on species which are sensitive to frequent fire. Most of the 'toothbrush-inflorescence' group of grevilleas may fall into this category. If so, this may form one explanation (yet to be tested) for the rarity of many of theses species today. *Grevillea beadleana* presently survives only in relatively fire-protected positions - on rocky platforms, between boulders or near creeks. Most of the Oaky Creek population occurs on the eastern side of the creek - perhaps the creek forms a buffer from fires that most frequently originate to the west. Similarly, the granitic bluff at Guy Fawkes protects surviving plants from most fires.

Even though the Guy Fawkes population is within a national park this has not diminished frequent fire. These come from both the west, running uphill from the Guy Fawkes River valley to the rim of the gorge and from the adjoining plateau, trickling down over the edge of the gorge. The recent fire in 1988 originated on the plateau and burnt several kilometres of forest understorey to the north and the south (J.B. Williams pers. comm.). Most fires in the area are illegally lit, presumably to enhance grazing. A Travelling Stock Route (TSR) adjacent to the Guy Fawkes River in the heart of the Park adds to the difficulties in controlling illegal grazing and associated burning off (G. Roberts pers. comm.).

Of particular interest are the apparent parallels in ecology and threatened status of several species in this 'toothbrush-inflorescence' group. For example, populations of the threatened *Grevillea caleyi*, which grow on lateritic ridgetops in the northern suburbs of Sydney, are susceptible to frequent burns (Scott 1986, A. Auld pers. comm.). Research on *Grevillea caleyi* suggests that fire should be excluded for at least 10 years to allow plants to mature, produce seed and build up a seedbank in the soil. Given that it seems to senesce after 30 years, occasional hot wildfire (say once every 20 years) may well be necessary for the successful survival of *Grevillea caleyi*. There is also some doubt about the effectiveness of a cool fire in promoting seed germination (A. Auld pers. comm.). The limited evidence on the ecology of *Grevillea beadleana* indicates that it may hold a similar reproductive strategy.

Fire, therefore, should not be viewed as incompatible with the existence of *Grevillea beadleana*. It would appear that it is vital to the regeneration of the species but is likely to be destructive if it occurs too frequently.

Other threats to the survival of *Grevillea beadleana* in the wild are habitat clearing, drought and grazing by sheep. In addition, its small population size at Guy Fawkes makes the species there vulnerable to the effects of inbreeding over the long term.

At Binghi there is the threat of physical disturbance of the habitat associated with the development of the leasehold land on which it grows. In 1989 some of the land on which *Grevillea beadleana* grows was illegally bulldozed by the lessee. Some plants of *Grevillea beadleana* were destroyed in the process and the disturbance resulted in localised soil erosion. Negotiations have since taken place between the lessee and relevant government authorities with a view to preventing further damage.

Another possible threat is grazing by goats. Several goat farms have been established on adjoining properties and if goats escape or were introduced into the naturally vegetated country, considerable damage could result (J.B. Williams pers. comm.). Any increase in grazing pressure, particularly on seedlings, could have an adverse impact on the populations of *Grevillea beadleana*.

Death of large numbers of individual plants during droughts is a possible important threat. Observations at Oaky Creek in July 1991 (Table 3) at the beginning of a major drought indicate this cause of mortality may be significant during dry times.

Future research

Specific research and management tasks have been outlined and costed in Benson (1991). Suggested projects include:

Additional survey: the Moona Plains locality should be re-surveyed in case *Grevillea beadleana* still exists there. Also, further botanical surveys in the Binghi granite area may locate additional populations.

Population dynamics: observations in 1991 revealed that at both its population sites, relatively large post-fire cohorts of *Grevillea beadleana* seedlings have survived for two years (Figure 7). Therefore it could be assumed that there are no major limitations with flowering, pollination, seed maturation and germination. Dispersal of the heavy seed appears to be limited to near the parent plant. However, experiments based on the tagging of both adult and juvenile plants would help substantiate the growth rates of the species, mean ages for the production of flowers and seed, seedling survival rate, longevity of individuals and mortality rates and causes. Research could also be warranted into seed viability, dormancy and response to heat and dispersal. Ants may play a role here because the seed is bordered by a waxy substance; similar seeds in related species are known to be gathered by ants (R. Makinson pers. comm.). To gain a better understanding of the fire regimes required to maintain populations, experimental burns of patches containing mature plants could be undertaken. Measurements should be taken of post-fire recruitment against the variables of temperature of the burn and post fire climatic conditions.

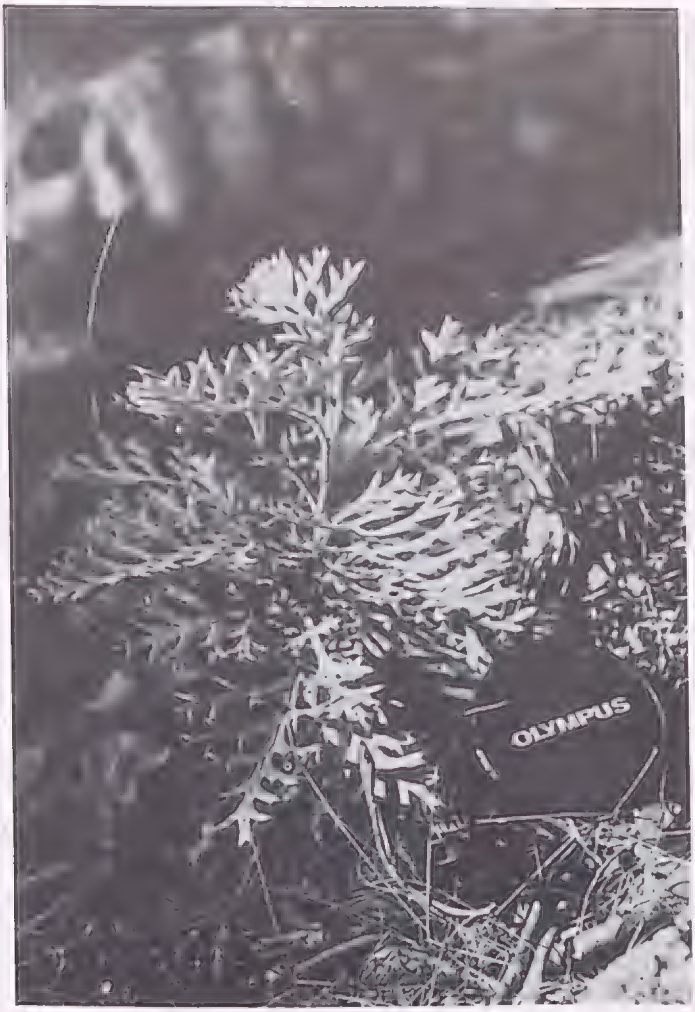

Figure 7. A two year old seedling. Parts of both the Guy Fawkes and Binghi populations of *Grevillea beadleana* were burnt in 1988. Adults are killed by fire and regeneration relies on seedlings.

Breeding systems: investigating the species' breeding system to establish its self compatibility and relative ratios of outcrossing to selfing would aid in indicating if inbreeding could be occurring in either or both of the populations.

Genetic variation: the presence of one large and one small population separated by 115 km allows for testing comparative differences in the genetic variability between the populations (R. Peakall pers. comm). The presence of any inbreeding in the smaller population could also be detected.

Conservation and management

Given that the species is endangered the main aim of management should be to maintain viable populations in the wild. This can best be achieved by preventing both populations from being burnt too often. It is inevitable that wildfire will burn each of the occurrences in the future, but every effort should be made to maintain a fire free period of at least 15 years (this suggested period is only an estimate at this stage pending the results of any future research into the species' fire ecology). The small population of *Grevillea beadleana* conserved in Guy Fawkes River National Park is in some ways the most threatened. It would seem that there needs to be better control on fires lit deliberately in the area including along the travelling stock route (TSR) in the valley. The removal of illegal livestock in the park, combined with the closure of the TSR could reduce some of the main incentives to start fires.

Protection of the large population of *Grevillea beadleana* at Oaky Creek, Binghi from inappropriate land use is a major management issue. This could be achieved either by acquisition of the land and its dedication as a nature reserve or by way of a secure covenant between the lessee and appropriate authority. Continuing destruction of nearby vegetation, construction of tracks and future recreational activities could adversely affect, indirectly or directly, this largest and most viable population of the species.

The protection of the habitat in the Oaky Creek valley would also benefit several other rare plant species - (*Prostanthera staurophylla, Hibbertia* sp. aff. *obtusifolia, Acacia torringtonensis, Acacia granitica* and *Persoonia terminalis* subsp. *terminalis*) and the *Eucalyptus prava-E. stannicola-E. andrewsii* plant association which is presently not represented in any conservation reserve.

If its population at Oaky Creek is conserved by way of a reserve or covenant and the appropriate authorities demonstrate they are able to control fire at both of its populations, then it would be justified to change the national threat status of *Grevillea beadleana* from endangered (E) to vulnerable (V).

Acknowledgements

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I especially wish to thank Mr Greg Roberts of the Armidale District Office of the New South Wales National Parks and Wildlife Service for organising the field survey, assisting with the gathering of relevant information and commenting on the text. I am grateful to Bob Makinson of the Australian National Botanic Gardens for advice on the taxonomic relationships of *Grevillea beadleana* and to J.B. Williams of the University of New England for advice on the flora of the Binghi region and commenting on the text. Thank you also to Judith Scott for preparing the figures.

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Distribution and abundance of *Blandfordia cunninghamii* Lindley (Blandfordiaceae)

C.L. Porter

Abstract

Porter, C.L.(Department of Applied Biology, University of Technology Sydney, P.O. Box 123, Broadway, Australia 2007) 1992. Distribution and abundance of* Blandfordia cunninghamii *Lindley (Blandfordiaceae). Cunninghamia 2(4): 523–532.* Distribution and abundance were compared in the rare *Blandfordia cunninghamii* and the more widespread *B. grandiflora* in the Blue Mountains of New South Wales. Environmental characteristics were studied at 13 sites. Approximately 750 plants of *B. cunninghamii* were found at 12 sites, nine of which are in conservation reserves. The habitat of *B. cunninghamii* is cooler and moister with more soil organic matter than that of *B. grandiflora*.

Introduction

Blandfordia cunninghamii Lindley (family Blandfordiaceae), one of four species in the genus, occurs in the Upper Blue Mountains and Illawarra regions of New South Wales. A rare species, it is coded 3RC- by Briggs & Leigh (1988), indicating some populations occur in conserved areas with the range exceeding 100 km, but the population size in reserves is unknown.

Another species, *B. grandiflora* R. Br., occurring in the Blue Mountains, has a more widespread range south from Fraser Island in Queensland to Sydney district.

The habitats of *B. cunninghamii* have damp soil (Beadle, Evans & Carolin 1982), and include hanging swamps at Kings Tableland, Wentworth Falls and Blackheath (Baker, Corringham & Dark 1984), rock ledges and in heath (Fairley & Moore 1989). Published localities for *B. cunninghamii* include: Blue Mountains, Mt Wilson, Wentworth Falls, Leura, Mt Kembla (Henderson 1987); Blue Mountains National Park; Illawarra State Recreation Area (Briggs & Leigh 1988); Wentworth Falls, Mt Tomah (Keith & Benson 1988).

The distribution and population size of *B. cunninghamii* and occurrence of *Blandfordia* species in the Blue Mountains were studied to confirm that populations are extant in the area, and to determine the range of communities and environments over which *B. cunninghamii* survives.

Methods

Distribution and population size

To confirm the distribution of the two *Blandfordia* species in the Blue Mountains, potentially suitable habitats were surveyed during summer 1989–1990, when the plants

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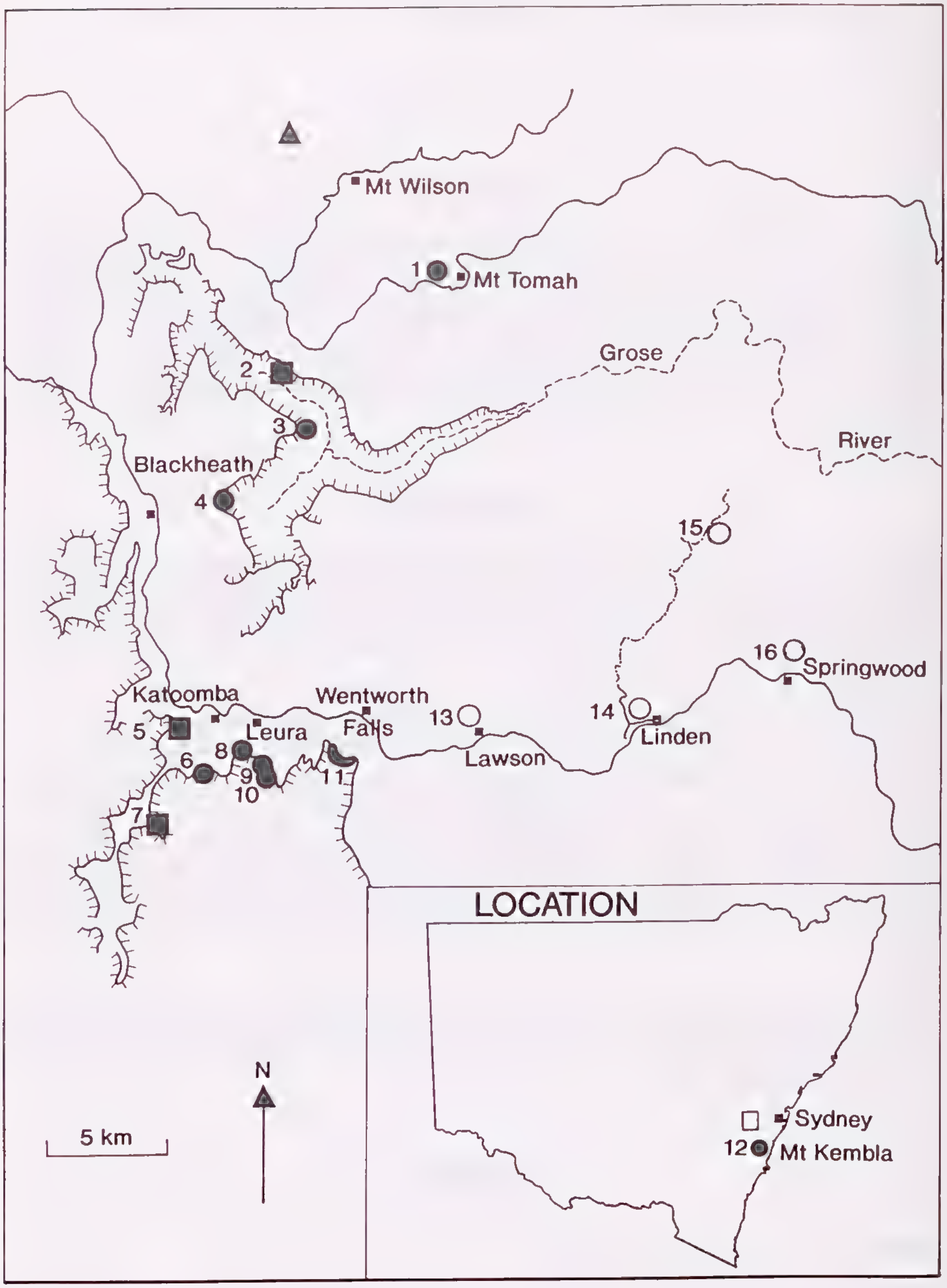

Figure 1. Distribution in the Blue Mountains of New South Wales of *Blandfordia cunninghamii*, localities confirmed (●); new localities (■) and prior collection locality not visited (▲) in this study; *B. grandiflora* (○) study sites. Localities listed in Table 1.

were easier to see if they were flowering. The survey was based on information about localities and habitats from herbarium specimens at the National Herbarium of New South Wales. Populations were counted in each site visited.

Site characteristics

Counting the plants in *B. cunninghamii* populations was difficult as individuals were often not distinctly separate but were in clumps of two or more. This was particularly so on rock faces where plants grew in a curtain of leaves, as at Mt Kembla. Typically *B. cunninghamii* plants were each approximately 30–50 cm in diameter and spaced 0.5–5 m apart. The area over which a population occurred was usually no more than 100 square metres. Most occurrences were on cliff edges, which affected the accuracy of counts.

Vegetative characters were often all that were available for identification of *Blandfordia*, as very few plants were flowering. Characters markedly associated with the particular species include: leaf margin crenulation, smooth in *B. cunninghamii* and crenulate in *B. grandiflora*; growth habit: *B. cunninghamii* leaves are laxer and *B. grandiflora* leaves have a distinct V-shaped cross-section. At a distance, it is difficult to differentiate *B. grandiflora* from juvenile *Xanthorrhoea* spp. and *B. cunninghamii* from *Lomandra longifolia* and occasionally from small, non-flowering *Gahnia* spp. (although *Gahnia* is scabrous). The leaves of *B. cunninghamii* are bright green and of similar width to those of *Lomandra longifolia* (though *B. cunninghamii* leaves are much longer and do not have a toothed leaf tip) and the leaf tips of *B. cunninghamii* are often necrotic. Numerous dark longitudinal veins (more obvious on the abaxial surface) along the length of the leaves is observed in *Blandfordia*. The number of veins ranges from 12–16 in *B. cunninghamii* and 6–10 in *B. grandiflora*.

Thirteen sites (nine populations of *B. cunninghamii* and four of *B. grandiflora*) representing the range over which the two species were observed were studied in detail in June 1990. At each site, attitude, aspect, slope and soil depth were recorded and three soil samples from the top 20 cm of the profile (excluding the A_0 horizon) were collected with an auger. Three replicates of each soil sample were analysed using the methods of Allen (1989) and pH, moisture content, organic content (estimated as % loss on ignition) and particle-size were measured. Site variation between the *Blandfordia* species in altitude, aspect, slope and soil depth was analysed by one-factor analyses of variance (Wilkinson 1987). Aspect data was transformed before analysis by subtracting 90° from each reading (and added after analysis). Variation in soil characteristics between-species in water content, loss on ignition, pH, % clay, % silt, % sand and % gravel was analysed by two-factor (*Blandfordia* species, site) nested analyses of variance (Wilkinson 1987) after averaging the replicate laboratory samples.

Associated species

Other vascular plant species rooted within one metre of each of three *Blandfordia* plants in the population were recorded. The pattern of plant species composition among the sites was analysed using hybrid multidimensional scaling (Belbin 1989). A two-dimensional ordination was used, with the Bray-Curtis dissimilarity measure, and a cut point of 0.8. The categorical nature of the pattern was tested using polythetic divisive clustering by indicator species analysis (Hill 1979).

Table 1. *Blandfordia* populations in the Blue Mountains: location, controlling authority of sites and estimated numbers of plants.

Site Number	Location	Control of land	Number of Plants (No. flowering 1989–1990)
1*	Mt Tomah	P.P.	20 (0)
2*	Pierces Pass	N.P.W.S.	45 (1)
3*	Blackheath	N.P.W.S.	40 (0)
4	Blackheath	N.P.W.S.	c. 30 (0)
5*	Katoomba-Cliff Walk	N.P.W.S.	25 (2)
6	Katoomba-Falls	B.M.C.C.	1 (0)
7	Katoomba-Narrow Neck	N.P.W.S.	3 (0)
8	Leura Cascades	B.M.C.C.	13 (0)
9*	Leura	N.P.W.S.	42 (0)
10*	Leura	N.P.W.S.	60 (0)
11	Wentworth Falls	N.P.W.S.	325 (0)
11a*	Wentworth Falls	N.P.W.S.	30 (0)
11b*	Wentworth Falls	N.P.W.S.	23 (0)
12*	Mt Kembla+	N.P.W.S.	100 (0)
13*	Lawson	N.P.W.S.	60 (1)
14*	Linden	B.M.C.C	200+ (1)
15*	Linden Ridge	N.P.W.S.	30 (1)
16*	Springwood	Crown Land	200+ (0)

* Denotes sites studied further; 1-12 *B. cunninghamii*, 13-16 *B. grandiflora*

+ Illawarra State Recreation Area

P.P. = Private Property; N.P.W.S = National Parks and Wildlife Service; B.M.C.C. = Blue Mountains City Council

Results

Distribution

The reported range of *B. cunninghamii* in the Upper Blue Mountains and at Mt Kembla was confirmed (Figure 1, Table 1). New locality records at Pierces Pass and Katoomba, also in the Upper Blue Mountains are indicated in Figure 1. Previously recorded sites of *B. cunninghamii* at Mt Wilson (specimen collected 1898) and at Yerrinbool (collected 1932) were not visited. Also one site reliably reported by R. Payne (in 1989) at Wedderburn could not be confirmed.

The occurrence of *B. grandiflora* in the Lower Blue Mountains was also confirmed. Based on personal observations and herbarium specimens, it is more widely distributed in the Lower Mountains than *B. cunninghamii* is in the Upper Mountains (note Figure 1 shows the study sites only of *B. grandiflora*).

The number of plants of *B. cunninghamii* within the boundaries of Blue Mountains National Park was approximately 620. Wentworth Falls contains 60% of these. The total number in all localities visited including Blue Mountains National Park was approximately 750 plants. Most of these plants (nine out of 12 populations) occur in areas controlled by the National Parks and Wildlife Service of New South Wales (Table 1).

Population size and flowering

Each population of *B. cunninghamii* was less than 100 plants (Table 1). For Site 11, all plants observed at Wentworth Falls were included (except 11a & 11b; two geographically separate populations used for study sites). This covers approximately two square kilometres and is comprised of numerous populations. *B. grandiflora* populations were generally larger, ranging from 30 to approximately 250 plants.

Three *B. cunninghamii* plants out of the total located (Table 1) flowered during summer 1989–1990 and none flowered during 1990–1991 (not shown on Table 1). More *B. grandiflora* plants were observed than *B. cunninghamii* plants to be flowering during 1989–90. The two sites in which *B. cunninghamii* flowered appeared to receive relatively high levels of solar radiation. At well-lit sites, such as along the National Pass at Wentworth Falls, leaves were generally broad with widths up to 15 mm, contrasting with plants in more shaded sites whose leaves were narrower.

Site characteristics

Examination of environmental data for the significance of the between-species variation (Table 2) indicate *B. cunninghamii* tends to occur at higher altitudes, on more southerly aspects and on steeper slopes than *B. grandiflora*, though Mt Kembla is of lower altitude. The soils at these sites are, as a result, more moist with higher organic content than the mostly north-facing *B. grandiflora* sites. Both species occur on acid soils. The most noticeable difference between sites of the two species is the sand content of their soils. Sand comprises approximately 80% of the soil on which *B. grandiflora* occurs, and between 50 and 75% for *B. cunninghamii*. Subsequently there is a higher proportion of silt and clay at sites where *B. cunninghamii* occurs.

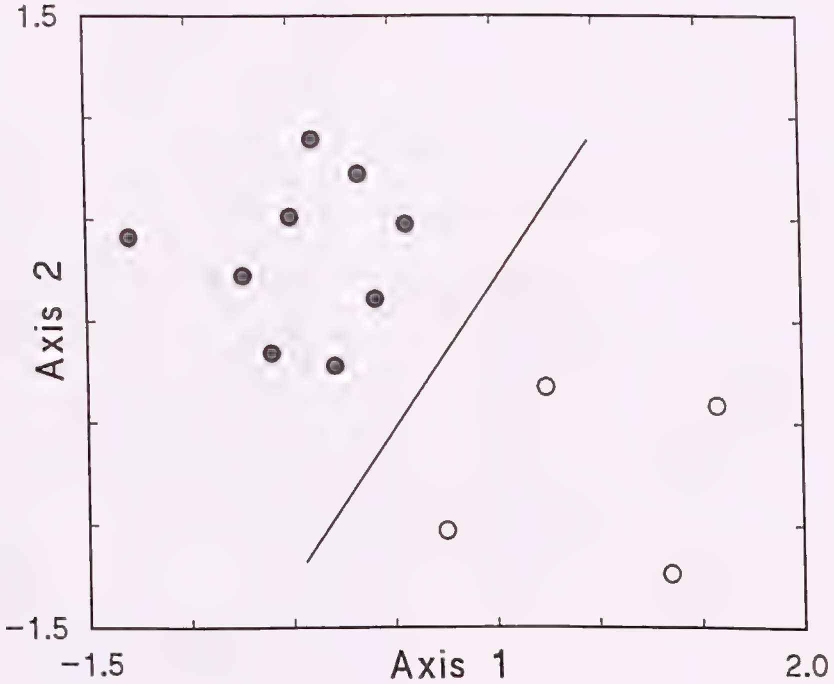

Figure 2. Two-dimensional hybrid scaling ordination of the plant species composition at the *Blandfordia cunninghamii* (●) and *B. grandiflora* (○) sites. The line indicates the principal division of the indicator species analysis.

Table 2. Average environmental characteristics at nine *Blandfordia cunninghamii* and four *B. grandiflora* sample sites

Environmental characteristic	***B. cunninghamii***									***B. grandiflora***				**Analysis of variance between-species**
	1	2	3	5	9	10	11a	11b	12	13	14	15	16	F
Site Characteristic														
Altitude (m)	920	670	720	960	900	880	820	820	500	680	530	520	330	10.57 *
Aspect (°)	216	204	162	135	160	130	216	216	186	20	10	344	200	20.23 *
Slope (°)	45	50	55	30	47	32	67	85	70	20	25	12	20	13.31 *
Soil depth (cm)	12	30	18	40	25	25	25	10	18	28	15	23	10	0.44 **
Soil Characteristic														
Total water content (%)	24.7	13.4	19.8	19.0	27.0	22.0	24.5	37.7	12.1	9.3	15.1	9.9	15.3	33.83 *
Loss on ignition (%)	15.1	6.7	6.8	8.9	9.5	5.4	7.3	15.2	7.7	2.8	8.4	3.7	5.7	27.22 *
pH	4.78	4.88	4.72	4.59	4.06	4.59	4.65	4.77	4.14	5.09	4.68	4.60	5.01	11.80 *
Gravel (>2.0 mm)(%)	3.6	51.4	11.1	11.1	9.1	2.9	2.4	4.8	7.2	7.7	3.3	2.0	4.3	3.59 **
Sand (0.05-2.0 mm)(%)	61.5	63.6	53.8	57.4	62.4	74.8	63.5	58.3	71.0	79.8	78.6	79.4	79.9	72.92 *
Silt (0.002-0.05 mm)(%)	14.1	17.6	24.6	14.8	19.0	9.9	15.4	19.8	13.7	7.9	8.0	7.3	8.5	65.74 *
Clay (<0.002 mm)(%)	24.4	18.8	21.5	27.9	18.6	15.3	21.1	21.9	15.3	12.3	13.4	13.3	11.5	25.79 *

Sand, silt and clay calculated as a percentage of non-gravel soil

* significant at $p<0.01$

** not significant at $p>0.01$

Localities listed in Table 1

Associated species

Ordination and clustering analysis of the floristic data (Figure 2) reveal two groups of sites. These correspond with the respective occurrences of the two *Blandfordia* species investigated thus indicating that each occurs with a distinct set of associated species. Of the 69 species recorded at more than one site (Appendix 1), 29 were recorded only at *B. cunninghamii* sites and eight only at *B. grandiflora* sites. Thus 46% of these widespread and common species occurred with both of the *Blandfordia* taxa. *B. cunninghamii* is associated with species commonly found in moist habitats, particularly damp rock faces, including *Acacia elata*, *Callicoma serratifolia* and *Ceratopetalum apetalum* in the overstorey, with an understorey of *Hakea dactyloides*, *Leptospermum polygalifolium*, *Stylidium productum*, *Dianella caerulea*, *Epacris pulchella*, *Gonocarpus teucrioides* and *Styphelia triflora*. *B. grandiflora* occurs with species more common in drier and more exposed areas often containing *Banksia serrata* in the overstorey, and an understorey of *Daviesia mimosoides*, *Entolasia stricta*, *Grevillea buxifolia* and *Platysace linearifolia*.

Two other rare plant species were found with *B. cunninghamii* at site 11a at Wentworth Falls, i.e. *Allania endlicheri* Kunth (Liliaceae), coded 3RCa (Briggs & Leigh 1988), growing on moist rock faces in the Blue Mountains and *Lomandra fluviatilis* (R.Br.) A.T. Lee (Lomandraceae), coded 3RC-. The latter species was not previously reported to occur on the Central Tablelands.

Discussion

The recording of distribution of *B. cunninghamii* in this survey was affected by access. All sites (except Sites 1 & 12) were located beside walking or vehicular tracks. Despite this, it is apparent that *B. cunninghamii* occurs at moist sites. Both species of *Blandfordia* are drought-tender (Bodkin 1986), but drainage may also be important to them, since all sites have some slope (Table 2). All *B. cunninghamii* sites have a significantly greater slope than *B. grandiflora* sites. This is inversely related to the sand content; the sand fraction is greater in *B. grandiflora* sites. The soils on which *Blandfordia* occurs in the Blue Mountains are mostly derived from sandstone, though *B. cunninghamii* was found also to occur on a sloping shale terrace at Pierces Pass (Site 2) and below the basalt cap of Mt Tomah (Site 1) where the plants are probably influenced by colluvium (second highest organic content (Table 2)).

Although two years is a short period to observe populations, it is clear that only very few plants of *B. cunninghamii* flower in some seasons at least. Low levels of seed set and germination may also be indicated in *B. cunninghamii* by the lack of juvenile plants. The exception was at Site 3 at Blackheath. This lack of juveniles may, however, be due to the recent absence of fire. Baker *et al.* (1984), state that *B. cunninghamii* 'occur in profusion after bushfires when the forest canopy is sparse'. In *Telopea speciosissima* and *Lambertia formosa*, flowering declines with time since the last fire after a peak approximately two years after a summer fire (Pyke 1983). In *B. nobilis*, peak flowering occurs one year after a fire (K.A. Johnson pers. comm.), and presumably this also occurs in *B. cunninghamii*. Plants of *Blandfordia* readily survive fire, as at Mt Tomah after a fire in 1976 (N. Rodd, pers. comm.). Although not documented, rapid growth with reproduction after fire in *Blandfordia* is almost certainly related to their underground rhizomes (Dahlgren, Clifford and Yeo, 1985). The longevity of *B. cunninghamii* plants is unknown, though from this survey it is clear that populations previously recorded are at least persisting.

Daviesia mimosoides was found to be a key associate of *B. grandiflora* as it occurred at the four sites studied in detail. Species with relatively high moisture requirement (Appendix 1) are indicators of probable presence of *B. cunninghamii* in the Upper Blue Mountains. These include *Hakea dactyloides*, *Leptospermum polygalifolium*, *Ceratopetalum apetalum*, *Callicoma serratifolia*, *Acacia elata* and *Smilax glyciphylla*.

At all *Blandfordia* sites exotic species are absent. The sites are mostly large distances from roads and picnic areas (minimal disturbance from external sources). Their low-nutrient soils generally do not provide good habitat for weeds. There is no perceived threat from exotic species to *Blandfordia* in the Blue Mountains.

Conservation

According to Briggs and Leigh (1988), for a species to be considered adequately conserved, there should be a minimum of 1 000 individuals in conservation reserves; conservation reserves in New South Wales being areas controlled by National Parks and Wildlife Service and the Forestry Commission. The known number of *B. cunninghamii* plants in conservation reserves is approximately 700. Hence, under the definition of Briggs and Leigh (1988), the conservation of this species remains inadequate (i). Surveys carried out shortly after fires may raise this status. It is unknown whether the single plant found at Katoomba Falls (Site 6) was originally part of a population that has diminished. The area of greatest concern is at Leura Cascades (Site 8) where there is severe trampling of the track edges, requiring some control of walking whilst retaining the aesthetic appeal of the area. Overall, however, the conservation status of *B. cunninghamii* is excellent, provided there is no further development in the escarpment/catchment areas of Wentworth Falls.

Acknowledgements

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APPENDIX 1

Average frequency of occurrence of plant species found in association with *Blandfordia*

Species	***B. cunninghamii***	***B. grandiflora***
PTERIDOPHYTES		
BLECHNACEAE		
+*Blechnum wattsii*	0.14	0.00
DENNSTAEDTIACEAE		
+*Hypolepis muelleri*	0.07	0.08
GLEICHENIACEAE		
+*Gleichenia rupestris*	0.11	0.08
+*Sticherus flabellatus*	0.07	0.00
LINDSAEACEAE		
+*Lindsaea microphylla*	0.04	0.08
ANGIOSPERMS-MONOCOTYLEDONS		
BLANDFORDIACEAE		
+*Blandfordia cunninghamii*	1.00	0.00
B. grandiflora	0.00	1.00
CYPERACEAE		
Caustis flexuosa	0.15	0.25
Lepidosperma laterale sens. lat.	0.11	0.17
Schoenus imberbis	0.00	0.17
IRIDACEAE		
+*Patersonia fragilis*	0.07	0.00
LILIACEAE		
Dianella caerulea	0.22	0.00
EPACRIDACEAE		
+*Dracophyllum secundum*	0.15	0.00
+*Epacris longiflora*	0.15	0.00
+*E. pulchella*	0.44	0.00
Leucopogon lanceolatus	0.07	0.00
Styphelia triflora	0.30	0.00
Woollsia pungens	0.04	0.25
ESCALLONIACEAE		
+*Quintinia sieberi*	0.15	0.00
EUPHORBIACEAE		
Amperea xiphoclada	0.22	0.08
FABACEAE-Mimosoideae		
+*Acacia elata*	0.11	0.00
A. terminalis	0.07	0.25
FABACEAE-Faboideae		
Bossiaea obcordata	0.00	0.17
B. scolopendria	0.00	0.17
Daviesia mimosoides	0.00	0.50
Dillwynia retorta	0.26	0.25
Gompholobium latifolium	0.07	0.00
Mirbelia rubiifolia	0.04	0.17
+*Pultenaea glabra*	0.11	0.00
P. scabra	0.11	0.25
GOODENIACEAE		
+*Dampiera stricta*	0.04	0.25
Goodenia bellidifolia	0.11	0.08
G. decurrens	0.33	0.17
HALORAGACEAE		
Gonocarpus teucrioides	0.33	0.08

Species	*B. cunninghamii*	*B. grandiflora*
LOMANDRACEAE		
Lomandra filiformis	0.07	0.00
L. gracilis	0.30	0.25
L. longifolia	0.04	0.17
L. obliqua	0.04	0.08
ORCHIDACEAE		
Terrestrial orchid	0.07	0.00
POACEAE		
Chionochloa pallida	0.41	0.17
Entolasia marginata	0.22	0.33
E. stricta	0.00	0.33
SMILACACEAE		
Smilax glyciphylla	0.19	0.17
XANTHORRHOEACEAE		
Xanthorrhoea sp.	0.15	0.00
ANGIOSPERMS-DICOTYLEDONS		
APIACEAE		
Platysace linearifolia	0.15	0.50
Xanthosia pilosa	0.22	0.08
X. tridentata	0.19	0.08
ASTERACEAE		
Olearia erubescens	0.15	0.00
CASUARINACEAE		
Allocasuarina littoralis	0.07	0.00
CUNONIACEAE		
+*Callicoma serratifolia*	0.15	0.00
+*Ceratopetalum apetalum*	0.19	0.00
MYRTACEAE		
+*Baeckea linifolia*	0.04	0.08
Leptospermum polygalifolium	0.41	0.33
L. trinervium	0.22	0.00
+*Tristaniopsis collina*	0.15	0.00
PITTOSPORACEAE		
Billardiera scandens	0.11	0.08
POLYGALACEAE		
Comesperma ericinum	0.11	0.00
PROTEACEAE		
Banksia ericifolia	0.11	0.00
+*B. marginata*	0.19	0.00
B. serrata	0.00	0.17
Grevillea buxifolia	0.00	0.25
G. sericea	0.00	0.17
+*Hakea dactyloides*	0.30	0.00
Lambertia formosa	0.04	0.08
Lomatia silaifolia	0.07	0.00
Persoonia laurina	0.07	0.00
+*Symphionema montanum*	0.07	0.00
STYLIDIACEAE		
Stylidium productum	0.52	0.00
RUTACEAE		
Boronia pinnata	0.07	0.08

Species recorded at only one site are omitted

+ Species noted by Beadle *et al.* (1982), or known to have a relatively high moisture requirement

Species nomenclature follows updated *Plants of New South Wales* (Jacobs & Pickard 1981)

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Aspects of the ecology of the rare *Grevillea kennedyana* (Proteaceae) in north-western New South Wales

Ann Duncan

Abstract

Duncan, A. (c/- National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, NSW, Australia, 2000) 1992. Aspects of the ecology of the rare Grevillea kennedyana *(Proteaceae) in north-western New South Wales.* Cunninghamia *2(4) 533–539. Grevillea kennedyana* occurs only in Sturt National Park and on adjacent pastoral properties in north-western New South Wales. The number of plants is estimated to be approximately 7 000. Population size and distribution of *Grevillea kennedyana* at Sturt National Park and adjoining properties in the north-western region indicate that the species does not appear to be threatened. Some survival mechanisms of this species are described.

Introduction

Grevillea kennedyana F. Muell. (family Proteaceae) is a shrub of restricted distribution occurring naturally in the extreme north-west of New South Wales. Conservation code is 2VCi, i.e. vulnerable with a range less than 100 km and inadequately reserved (Briggs & Leigh 1988). 'This species is not closely related to any other eastern Australian *Grevillea* species but does have some affinity with *Grevillea juniperina* R. Br. and *G. victoriae* F. Muell. However, it differs from these most significantly in its very oblique torus and its longer ovarian stipe as well as its lack of stylar indumentum, among other things. It shares most features with and appears closely related to *Grevillea acuaria* F. Muell., a Western Australian species,' (P. Olde, pers. comm.).

Prior to this study, populations of *Grevillea kennedyana* were known from mesa slopes at Mount Wood and Olive Downs in Sturt National Park (latitude 29°00' – 29°45' S, longitude 141°40' – 142°05' E) and at the nearby pastoral properties of Onepah to the east and Yandama to the south. The scree slopes of these mesas consist of extensive remnants of a formerly extensive duricrust of silcrete that weathers to moderately coarse fragments overlying brown, loamy lithosols (Geological Survey of New South Wales 1967).

Vegetation is semi-arid low woodland dominated by *Acacia aneura, A. cambagei* and *Atalaya hemiglauca*, with occasional *Casuarina pauper* up to seven metres high. The associated low shrubs include *Eremophila freelingii* (predominant upslope); other species are *Acacia tetragonophylla, Scaevola spinescens,* and species of *Eremophila* and *Senna.* A low chenopodiaceous ground cover is invariably present.

Following the discovery of a third population in Sturt National Park, at McDonalds Peak, an assessment of population size and ecology of *Grevillea kennedyana* was commenced.

Methods

Separate populations of *Grevillea kennedyana* at Mount Wood, Mount Wood Hills, McDonalds Peak, Olive Downs Escarpment and Onepah (Fig. 1) were either counted or estimated. Site differences of aspect, slope, and canopy cover at Mount Wood and at Trig Hill within the Mount Wood Hills were examined. The population age structure, stem size and number, height and canopy cover were recorded on three 100 m^2 study sites at Mount Wood.

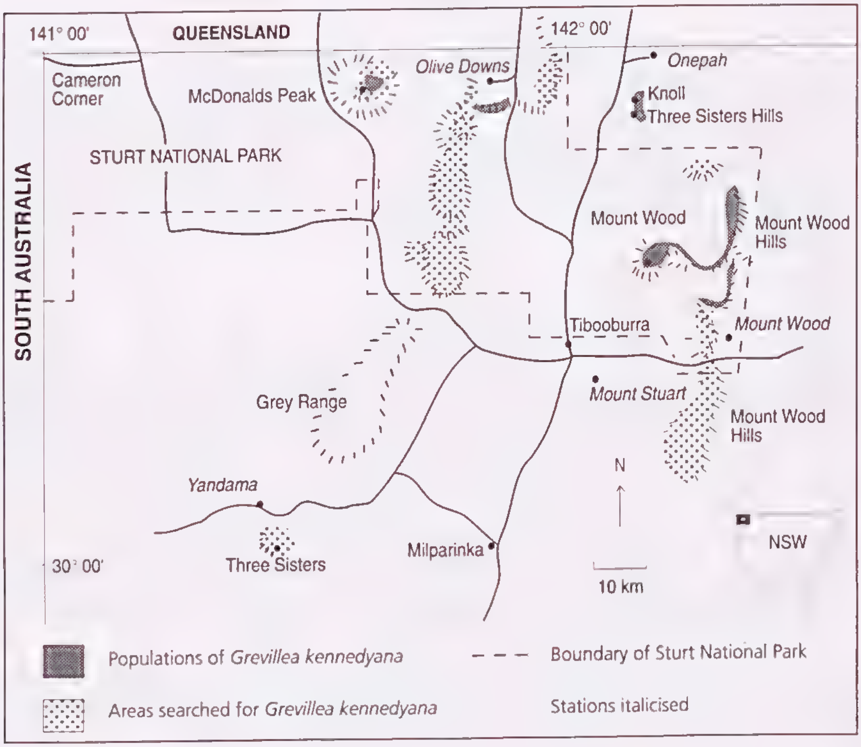


Figure 1. Locations of *Grevillea kennedyana* in north-western New South Wales

Rainfall data were obtained from the Bureau of Meteorology and unpublished records at Tibooburra. Observations on fire regime and pattern were provided by Mr R. Betts, a local resident.

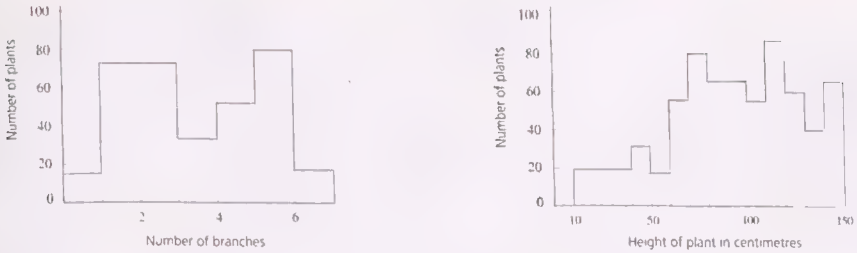
Growth pattern

Grevillea kennedyana is a many-branched shrub arising from either ground level or a consolidated stump (Fig. 2a). Few plants possess more than six thick stems and the majority of these branches are between 4 cm and 8 cm in circumference (Fig. 2b). Overall shrub height is between 0.7 m and 1.5 m, (Fig 2c). An occasional 2 m plant has been observed.

A distinctive feature of *Grevillea kennedyana* populations is the close grouping of plants. Such groups consist of 4 to 8 close growing plants with intertwining branches. Canopies of isolated individual plants average 1.5 m^2, but a group or colony can result in

Figure 2a Number of branches on the plants

2c Height of plants



2b Stem sizes

2d Canopy width

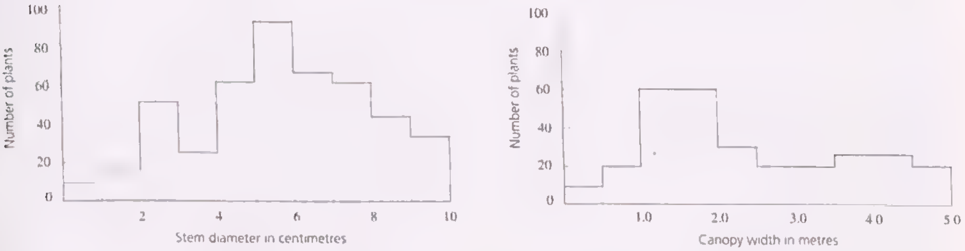


Figure 2. Number of branches, height, stem size and canopy width of *Grevillea kennedyana* plants at Mount Wood

a combined canopy of 3–5 m^2 (Fig. 2d). Formation of most groups appears to be coppicing from roots. This phenomena was most pronounced at Onepah where investigations indicated that the individuals forming a colony had connecting horizontal roots. Other groups may have resulted from seedling establishment near an adult plant.

Distribution and population size

Population counts took these groups into consideration by treating them as one individual. Large populations, ≥ 100, were estimated by counting the number of isolated individual plants and canopies. In smaller populations where plants could be studied individually, difficulties were sometimes experienced in distinguishing between seed-generated and coppicing stands, as this was impossible to confirm without digging up individual plants. Overall total population numbers may be underestimated.

Grevillea kennedyana locations in north-west New South Wales are shown in Fig 1. Its range is only 70 km. The estimated number of plants is now about 7 000 (Table 1). Localised populations of the species are fragmented and discontinuous, with major concentrations at Mount Wood, McDonalds Peak, and East Olive Downs Escarpment. Limited exploration at Yandama failed to locate the previously recorded population, (*Collier*, 1960 NSW 93160).

Altitude range for *Grevillea kennedyana* is from 140 m at Mount Wood to 200 m at Olive Downs. A horizontal concentration of plants midslope is frequently apparent, with an upslope limit about 20 m below ridge crest. Slope ranges from almost level (about 10°) to steep (about 75°) and aspect through 360°.

Table 1. Population numbers of *Grevillea beadleana*

Locality	Total No.	Population range of localised groups
Mount Wood	1 500	30 – 400
Mount Wood Area	650	1 – 200
Mount Wood Hills	> 1 500	1 – 250
McDonalds Peak	900	1 – 100
Olive Downs Escarpment	1 600	47 – 400
Onepah	750	10 – 300
Yandama	–	
Total number	6 900	–

Table 2. Canopy Cover

Mount Wood (29°20'S, 142°10'E)		Trig Hill (29°28'S, 142°11'E)	
Tall shrubs	4%	Tall shrubs	55%
Medium shrubs	6%	Medium shrubs	30%
Grevillea kennedyana	30%		
Low chenopods	60%	Low chenopods	15%
Aspect	0–360°		0–360°
slope	30–45°		45°
Surface	covering of large silcrete rocks		covering of large silcrete rocks

Concentrations of *Grevillea kennedyana* occur where there is little or no other canopy cover and a sparse, low, chenopodiaceous cover between plants of *Grevillea kennedyana* (Table 2). Smaller populations are usually in clearings where trees and taller shrubs are absent. At Mount Wood where the shrub canopy cover is only 10%, *Grevillea kennedyana* cover is 30%. However, at Trig Hill, Mount Wood Hills, where *Grevillea kennedyana* is not present, the shrub canopy cover is 85%. Both Mount Wood and Trig Hill are designated Flat Top (land system series Sheet 54–7). The absence of *Grevillea kennedyana* plants from Trig Hill suggests that this high proportion of canopy cover may be a factor in habitat selection.

The region has low rainfall, 236 mm per year, with a peak in January when isolated summer storms are experienced (Figure 3). There are long periods without precipitation, but the rain that falls in summer is sometimes torrential, so that infrequent though these episodes are, the relative importance of running water as an agent to disperse seeds may be high. Although most larger populations are found on slopes, the frequently observed occurrence of smaller populations of *Grevillea kennedyana* along streams or drainage lines may reflect seed movement by water.

The main Grey Range is similar geologically to McDonalds Peak and Olive Downs escarpment – Tertiary sediment (*Geological Survey of NSW* 1967) – but the absence of *Grevillea kennedyana* from large sections of the Range is not explained (Figure 1). On the slopes of the main Range the underlying erodible material is exposed without a covering of larger rocks, indicating a possible correlation between the nature of the scree slope and the species occurrence. *Grevillea kennedyana* appears to be associated more frequently with slopes containing a higher proportion of rough silcrete scree.

Ecology and management of *Grevillea kennedyana*

The ecology of *Grevillea kennedyana* involves episodes of drought and fire. Life expectancy of mature shrubs is unknown. Although branches greater than 12 cm in circumference are rarely seen, stems up to 20 cm have been observed. Generally, there is very little evidence of plant senescence. Though many *Grevillea* species are short-lived, some are long-lived. An individual of the tree species, *Grevillea striata*, a dense-wooded tree, at Poole's grave near Milparinka, just south-west of Sturt National Park, marked by Sturt in 1845, is still surviving nearly 150 years later.

Flowering occurs during winter and spring, becoming sporadic during drought. The pollinators are unknown, but flower size, red flowers and long styles suggest that it is likely to be bird-pollinated. *Grevillea kennedyana* does not appear to retain fruit or seed in the canopy for long periods after maturation. No fruits were observed during this survey. Regeneration is by seed or vegetatively. Maconochie (1982) suggests that on clay soils regeneration of many arid zone plant species is from seed, either stored in the ground or freshly fallen, and only occurs at irregular intervals under favourable conditions. Populations of *Grevillea kennedyana* consist of mixed size stands which probably relate to different ages. The most recent recruitment from seed would possibly have been after reasonable rain in 1988–89. Other years of regeneration could have been 1984, 1974–76. Resprouting or coppicing, the alternative regenerative method, may enable established individuals to survive and expand under stressed conditions. Observations indicate that *Grevillea kennedyana,* though it does not possess obvious storage organs, has the ability to resprout from adventitious buds in stems (branches), bases and roots. The ability to produce these buds has been observed in many desert plants (Kasses 1966). Stimulation of new growth can be caused by physical damage. Exposure and damage of roots and branches may be caused by macropods as *Grevillea kennedyana* clumps are favoured as rest pads.

The evolutionary significance of fire for Australian arid zone species is not adequately understood. The frequency, intensity and season of fires has radically altered in the last 100–150 years. Overgrazing by domesticated and feral animals, with increased grazing by macropods within the park, together with the predominance of *Atriplex vesicaria*, a species of low flammability (Hodgkinson 1982), has greatly reduced the

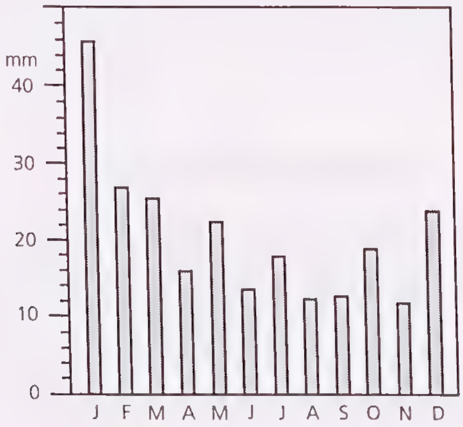


Figure 3. Average monthly rainfall (mm) for Tibooburra 1962—1991

frequency of fire. Since 1975 there have been no fires in the study areas (Mr R. Betts, pers. comm.).

The browsing pattern by animals may also have changed. In general, there is very little evidence of browsing on mature plants. Prior to 1973 all areas would have been grazed by sheep, which prefer chenopodiaceous species (Davey 1983). Since the formation of Sturt National Park and the subsequent removal of livestock, the numbers of Red Kangaroos *(Macropus rufus)* and the Euro *(M. robustus)* have increased. The major component of their diet is grass but in times of drought the Red Kangaroo has been recorded consuming sharp-spined *Sclerolaena* species (Davey 1983), so under severe drought conditions it is possible that *Grevillea kennedyana* may be browsed.

On the pastoral property of Onepah 30–40 plants of *Grevillea kennedyana* 10–12 cm high had numerous densely leaved shoots sprouting from single 1 cm diameter stems. A possible explanation is vegetative recovery after heavy browsing. Kangaroos and rabbits are present on the property but the main browsers are stock. Prior to 1989 sheep were the main animals but they have now been replaced by cattle. Similar reshooting plants were not observed within Sturt National Park.

The rabbit populations were drastically reduced subsequent to the 1950s and the introduction of myxomatosis, but numbers are again increasing. Rabbits are versatile feeders and the impact on regeneration of *Grevillea kennedyana* is unknown. Studies on *Acacia carnei* at Kinchega National Park demonstrated that rabbits graze not only on suckers or seedlings, but also chew roots (Benson 1991). To test the relative importance of rabbit and kangaroo grazing on the survival of young plants, wire cages would need to be erected to exclude either or both these animals. Although goats are a problem elsewhere in western New South Wales, currently they do not constitute a problem in Sturt National Park.

At present the population of *Grevillea kennedyana* does not appear to be threatened in the short term. The disjunct nature of the habitats tends to protect the species even though a local population catastrophe may occur. The majority of the populations are contained within Sturt National Park and are subject to strict conservation practice. With two mechanisms of regeneration, seed and vegetative reproduction, the species may cope adequately with the two major environmental influences of fire and drought. Plants appear to have the potential to live for decades. The absence of young seedlings suggests a possible long-term threat and the monitoring of study areas would indicate whether this is due to animal herbivory or seasonal conditions. Approximately 90% of the population of *Grevillea kennedyana* (over 6 000 plants) is in Sturt National Park and it would therefore appear appropriate to consider revising the conservation status from 2VCi (Briggs & Leigh) to 2VCa.

Acknowledgements

The field work for this study was carried out in Sturt National Park and I wish to thank Paul Jennings, Supervisor at Tibooburra, whose own astute observations in locating the McDonald Peak population prompted this paper, and his colleagues for their continued support. I also greatly appreciate the ecological suggestions by Doug Benson, comments on the manuscript by Bob Makinson, talks with *Grevillea* author Peter Olde, local pastoralist Ross Betts for fire records, Kevin Smith at Tibooburra for rainfall data and Lyn McDougall for drawing the figures and typing the manuscript.

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The natural vegetation of the Penrith 1:100 000 map sheet

D.H. Benson

Abstract

Benson, D.H. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, New South Wales, Australia 2000) 1992. The natural vegetation of the Penrith 1:100 000 map sheet. Cunninghamia *2(4) 541–596.* The composition and extent of the present natural vegetation on the Penrith 1:100 000 map sheet 9030 (lat. 33° 30' – 34° 00' S, long. 150° 30' – 151° 00' E) is mapped and described in terms of structure and characteristic species. Eighteen plant communities are recognised including tall open-forests, open-forests, woodlands and sedgelands. Vegetation patterns relate strongly to underlying geology with major groups of communities being restricted to either Wianamatta Shale, Tertiary alluvium, Holocene (Recent) alluvium or Hawkesbury Sandstone. Within these groups, patterns relate to rainfall gradients and soil drainage conditions. Comments are made on the adequacy of the major conservation reserves and botanically significant species are indicated. Conservation issues relate to different land uses on major geological types. Western Sydney's Cumberland Plain makes up the major part of the Penrith sheet; because of the suitability of its soils and terrain for agriculture and suburban development, very little of its vegetation remains and very little of this is conserved. Of 84 species regarded as having particular conservation significance in western Sydney, 44% were recorded in Cumberland Plain Woodlands and 36% in River-flat Forests (including freshwater wetlands), highlighting the need for better conservation of remnants of these vegetation types.

Introduction

'One immense tract of forest land extends, with little interruption, from below Windsor, on the Hawkesbury, to Appin a distance of 50 miles', wrote James Atkinson in 1826. Since then, this forest land has virtually disappeared, replaced by farms, factories and suburban estates. One hundred and sixty years later the few remnants of forest remaining still lack adequate long-term protection.

As part of the Sydney Region Vegetation Map Series, this paper describes the vegetation of the Penrith 1:100 000 map sheet area and, in particular, draws attention to how little remains of the vegetation of western Sydney.

Location, physiography and climate

The Penrith 1:100 000 Vegetation Sheet (based on the Penrith 1:100 000 Topographic Sheet 9030, AUSLIG, Canberra) is bounded by latitudes 33°30' and 34°00' S, and by longitudes 150°30' and 152°00' E. It covers the western region of Sydney extending from Parramatta westward to Springwood on the lower Blue Mountains, and from Kurrajong in the north to Bringelly in the south. This includes the central basin of the Cumberland Plain, which lies between Parramatta and the Blue Mountains, and extends from Richmond in the north to Picton in the south (Figure 1). This is gently

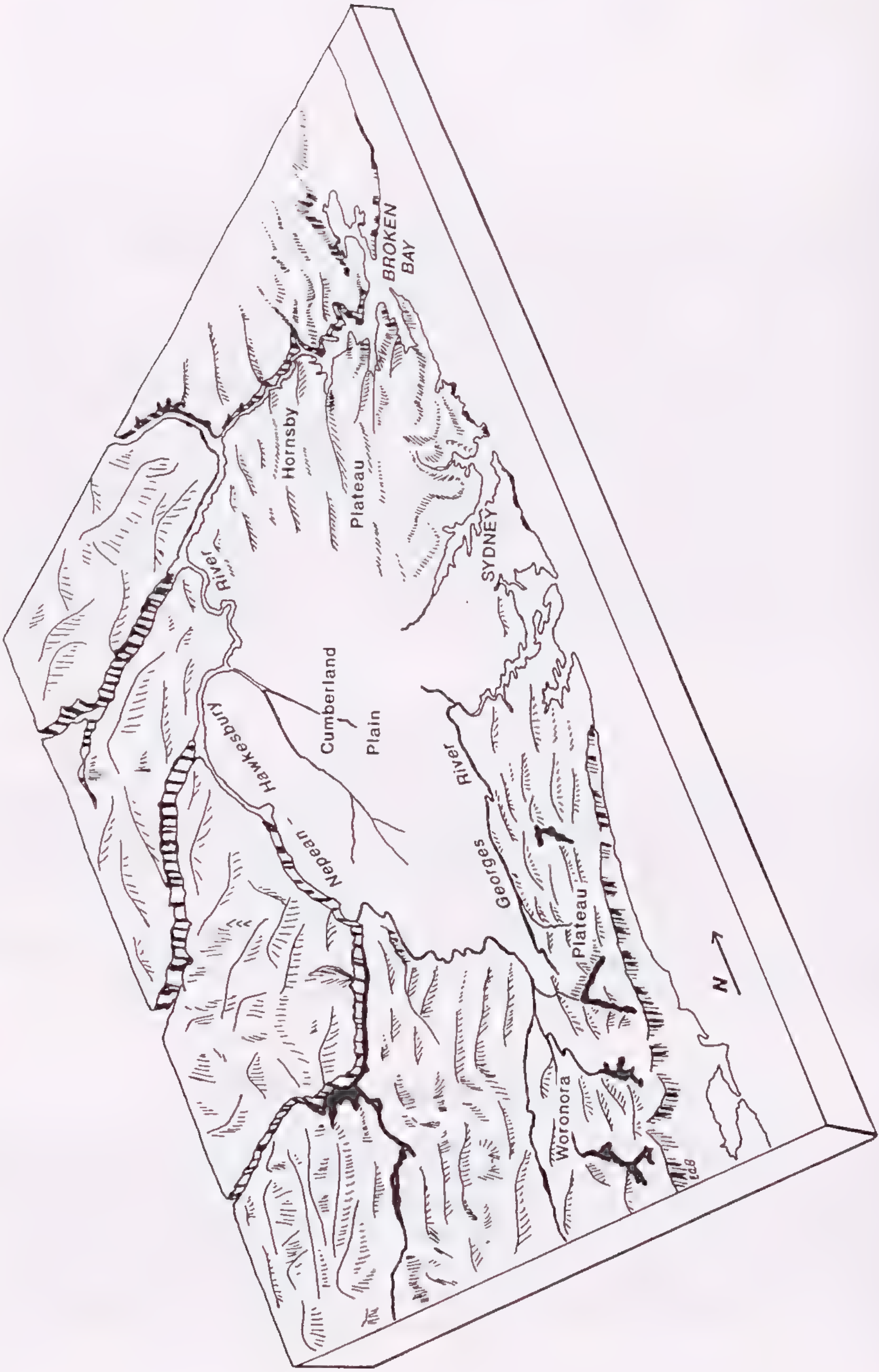


Figure 1. Block diagram of Sydney showing topography of the Penrith sheet area centred on the Cumberland Plain.

undulating to hilly country (altitude generally ranging from 20-100 m a.s.1.), on Triassic Wianamatta Group shale (New South Wales Department of Mines, 1966) and contrasts with the rugged Hawkesbury Sandstone of the lower Blue Mountains and coastal Sydney area.

The Cumberland Plain is bounded on the north and west by the Hawkesbury–Nepean River. Along this river and associated creeks (South Creek, Rickabys Creek, Eastern Creek), and the Georges River, are extensive alluvial deposits of Holocene (Recent) geological age. The largest deposits are on the floodplain of the Hawkesbury River, between Penrith and Windsor, and along the Nepean River near Camden. The fertile agricultural soils formed from these deposits were eagerly sought by the early European settlers who established farms near Windsor in the 1790s. As a result most of these areas are now completely cleared of native vegetation and indeed had probably been cleared by the 1830s.

Between Penrith and Windsor are older alluvial deposits of gravel, sand, silt and clay of mainly Tertiary age, deposited by an ancestral Hawkesbury–Nepean river system (Gobert 1978). Many of these deposits still retain their original natural vegetation though this is being destroyed by extensive sand, gravel and clay extraction and piecemeal suburban expansion.

Along the western edge of the Cumberland Plain, the lower Blue Mountains rise from about 200 m a.s.1. along the Lapstone Monocline at Glenbrook to 500 m at the western margin of the map sheet. They form a dissected plateau of Hawkesbury Sandstone of Triassic age but stratigraphically lower than the Wianamatta Shale which covers the downwarped Cumberland Plain. Remnant Wianamatta Shale cappings persist along the sandstone ridges followed by the Great Western Highway as far west as Faulconbridge and as far as Mt Tomah on the ridge followed by Bells Line of Road. Hawkesbury Sandstone borders the northern edge of the Cumberland Plain and occurs extensively between Annangrove and Cattai in the north-eastern corner of the Penrith Sheet and near the Georges River in the south-east corner. Many areas of Hawkesbury Sandstone still carry relatively undisturbed natural vegetation.

A number of volcanic outcrops (mostly diatremes) occur on the sheet area, though most have been cleared of native vegetation including the largest, at Prospect. Smaller uncleared outcrops are found in the Blue Mountains.

Soil landscapes of the Penrith sheet (Bannerman & Hazelton 1990) relate strongly to geology and can generally be associated with characteristic natural vegetation. Soils derived from Hawkesbury Sandstone are strongly acid. They are characteristically deficient in phosphate and are often locally deficient in nitrogen. Soils from the Wianamatta Group are strongly acid and intrinsically deficient in phosphorus, nitrogen and calcium.

Average annual rainfall on the Cumberland Plain is low. It is highest on the eastern edge (Parramatta 911 mm p.a.) and decreases westward (St Marys 759 mm, Windsor 757 mm, Bringelly 760 mm p.a.), increasing again with the rising elevation of the Blue Mountains (Faulconbridge 1 150 mm, Bilpin 1 300 mm p.a.). Mean maximum temperatures for January are 28–29°C for most of the sheet (e.g. Parramatta 28.1°C). The highest maximum temperature recorded for Parramatta is 46.3°C. Mean temperatures for July are highest on the eastern side (Parramatta 4.5°C) and decrease westward (Richmond 3.6°C). Frosts are common on the Cumberland Plain and the lowest minimum temperature for Richmond is -8.3°C. (Figures from Bureau of Meteorology, 1979).

In terms of regional rainfall the Penrith map sheet area is almost wholly within Zone 3 of Edwards' (1979) rainfall zones which extends to the northwest of New South

Wales. Stations within this zone have median annual rainfall of 440–810 mm and a tendency for a higher proportion of that annual total to occur in the warmer months of the year. In the Penrith area, as well as being greater, the summer rainfall is less variable than the winter rainfall (Figure 2).

Soil moisture availability in this zone is relatively high throughout the year reaching a peak in winter when the lower rainfall is more than compensated for by the low evaporation. Plant growth is limited by low temperatures during winter and by low soil moisture at other times.

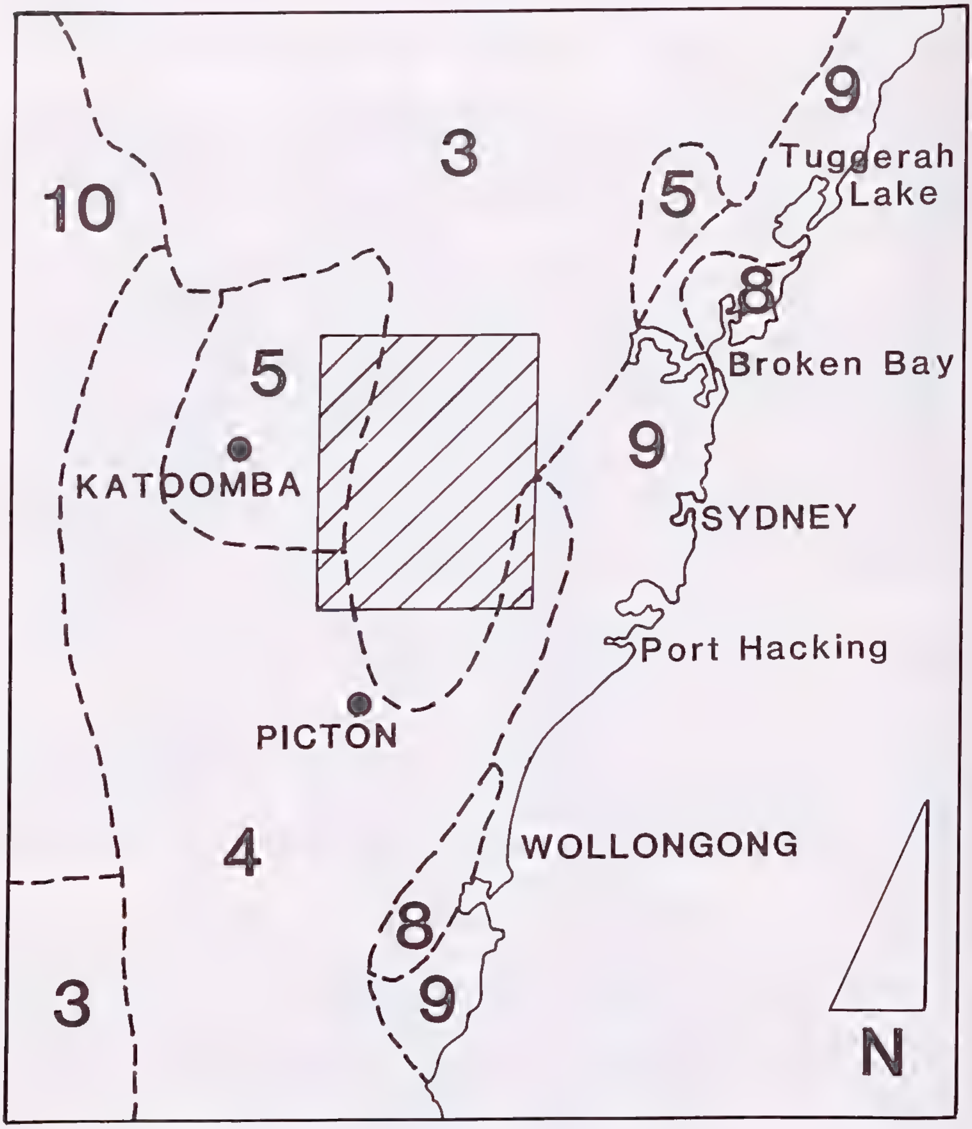


Figure 2. Location of Penrith map sheet area showing rainfall zones of Edwards (1979). Stations within zone 3 have median annual rainfalls of 440-810 mm with a higher proportion occurring in the warmer months. Adjoining zones 4, 5 and 9 receive higher rainfall.

Methods

Areas of vegetation with similar structure (Specht 1970) and floristics (dominant species) were grouped to form the map units on the basis of aerial photopatterns and recognisable geological and landscape characteristics. Black-and-white aerial photography from the New South Wales Department of Lands (Penrith 1:40 000 scale taken in September 1979) was used initially and updated with late–1988 and early–1989 photography. Compilation maps were prepared at 1:25 000 scale and subsequently reduced to 1:100 000 scale.

Present-day (i.e. 1989) vegetation is mapped, but comments on the original natural vegetation of some agricultural and urban areas are also provided. An alphanumeric code is used to distinguish individual plant communities. The numeric code represents the structural form of the plant community and the alphabetic code represents the characteristic species. The codes used are consistent throughout the Sydney Region 1:100 000 Vegetation Map Series, allowing map units to be cross-referenced (Benson 1986, Keith & Benson 1988, Benson & Keith 1990).

There are a number of constraints in reducing the complex pattern of natural vegetation to a map format. The map units recognised are not all of equivalent rank. Some are essentially land units made up of several plant communities associated with a particular geological or physiographic type (e.g. map units 28a) whereas others are more clearly plant associations (*sensu* Beadle & Costin, 1952) (eg. map units 10c, 14a). Generally the term 'plant community' is used for the basic vegetation unit. Map units have also been provided with common names based loosely on habitat and composition, for ease of reference.

The vegetation map is a diagrammatic attempt to simplify the distribution patterns of an often rich and varied flora, over an extensive region. It is scale-dependent and map units will almost invariably include unmapped areas of other map units too small to be shown separately. Similarly, most plant communities do not have clear-cut boundaries but grade into each other, often over a broad ecotone. For mapping purposes such boundaries have to be represented by a line.

Field checking has been carried out intermittently between 1975 and 1990, and included notes on structure, characteristic species of major strata and associated environmental factors. Extensive species lists were compiled for particular areas. Available species lists are listed in bibliographies such as those of Pickard (1972), Bryant & Benson (1981) and Keith (1988); copies of some of these are available from the Royal Botanic Gardens Library.

Specific sets of data were collected for the Wianamatta Shale and Tertiary alluvium. The Wianamatta Shale data consisted of 100 sites, each 400 m^2 in area, randomly located in Western Sydney, for which species presence had been recorded. Data collection was carried out between 1973–1978. The Tertiary alluvium data was of 30 similarly recorded sites, collected between 1978–1980 on a grid basis. Basal area and plant density data from these sites has been presented for some plant communities. A high frequency of small size classes, for example, probably indicates a period of regeneration following clearing or logging. Such data give an indication of community dynamics as well as providing guidelines for regeneration and planting programs.

Botanical names used are those currently recognised at the National Herbarium of New South Wales. For authorities see Jacobs & Pickard (1981), with alterations in Jacobs & Lapinpuro (1986), or Harden (1990–1991).

Vegetation

The Penrith area was explored within months of the settlement at Port Jackson in 1788 and accounts of the expeditions of Governor Arthur Phillip, John Hunter and Watkin Tench exploring the Nepean–Hawkesbury River include descriptions of the landscape and its general vegetation (see Benson & Howell 1990*a*). References to the occurrences of particular species occur in the writings of George Caley (Currey 1966) and Allan Cunningham (Lee 1925). The strong correlations between the type of vegetation and the potential agricultural value of the land was frequently commented upon. In particular the marked differences between the Hawkesbury Sandstone landscapes and those of the heavier-textured and agriculturally superior soils developed from Wianamatta Shale and alluvium of the floodplains were frequently observed. For example, Allan Cunningham reports in his journal on 23 December 1816, after travelling from Parramatta to Sydney: 'As I advanced on the Road, I observed that the Botany fell off, on some rich pasture lands that I pass'd, and [on] those spots where the Vegetable Kingdom appear'd in greater Luxuriance their exuberance was a certain indication of the Sterility of the Soil.'

Scientific study of the plant communities began with Pidgeon (1937, 1941) who described general differences in vegetation on Wianamatta Shale and Hawkesbury Sandstone in the Sydney Region. Phillips (1947) described the main plant communities of western Sydney and Forster *et al.* (1977) included descriptions based on early work by the present author though neither work included detailed mapping. The distribution of the original vegetation of the floodplain of the Nepean-Hawkesbury River has been mapped (Benson 1974). A recent account of the vegetation of the Sydney area, defined by the County of Cumberland, describes and maps eight major vegetation types (Benson & Howell 1990*a*). A modified section of that map showing the extent of natural vegetation in 1788 for the Penrith map area is given in Figure 3. As this map sheet deals with about half of the area covered by Benson & Howell, the relationship between those vegetation types and the map units described here is given in Table 1.

Table 1. Vegetation types of Benson & Howell (1990*a*) (in bold) with corresponding map units and codes.

Turpentine - Ironbark Forest	Turpentine - Ironbark Forest	9o
Cumberland Plain Woodlands	Spotted Gum Forest	9b
	Shale/gravel Transition Forest	9d
	Grey Box Woodland	10c
	Grey Box - Ironbark Woodland	10d
Castlereagh Woodlands	Shale/gravel Transition Forest	9d
	Castlereagh Ironbark Forest	9e
	Castlereagh Scribbly Gum Woodland	14a
	Agnes Banks Woodland	14b
	Swamp Woodland	14c
River-flat Forests	Camden White Gum Forest	6d
	River-flat Forest	9f
Sandstone heaths, woodlands & forests	Sydney Sandstone Gully Forest	10ag
	Sydney Sandstone Ridgetop Woodland	10ar
	Lower Blue Mountains Heath (part)	21f
Freshwater and Estuarine wetlands	Estuarine Complex	4a
	Freshwater Reed Swamps (floodplain wetlands only)	28a

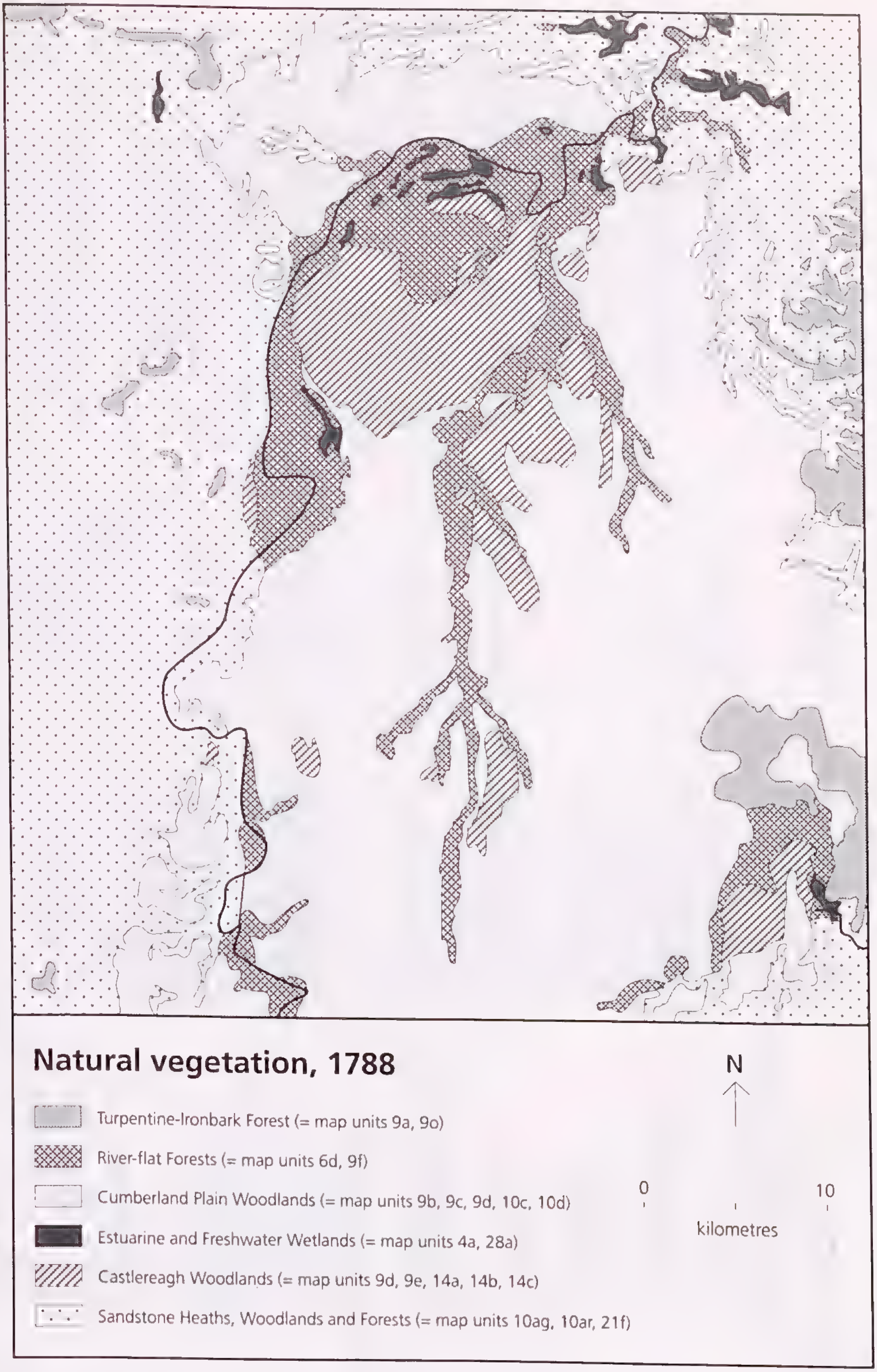

Natural vegetation, 1788
N
Turpentine-Ironbark Forest (= map units 9a, 9o)
River-flat Forests (= map units 6d, 9f)
Cumberland Plain Woodlands (= map units 9b, 9c, 9d, 10c, 10d)
Estuarine and Freshwater Wetlands (= map units 4a, 28a)
Castlereagh Woodlands (= map units 9d, 9e, 14a, 14b, 14c)
Sandstone Heaths, Woodlands and Forests (= map units 10ag, 10ar, 21f)
0
10
kilometres

Figure 3. Presumed 1788 or pre-European pattern of natural vegetation of the Penrith map sheet area.

Table 2. Map unit, common name, structure, main canopy species, geology and occurrence of plant communities in the area covered by the Penrith 1:100 000 map sheet.

Map Unit	Structure	Main canopy species	Geology	Occurrence
4a	**Estuarine Complex**			
	Open-scrub	*Avicennia marina* *Aegiceras corniculatum*	Holocene alluvium	Estuarine mudflats regular tidal inundation
	Rushland / Reedland	*Juncus kraussii* *Phragmites australis*		Infrequent inundation. Brackish water
	Low open-forest	*Casuarina glauca*		
	Open-scrub	*Melaleuca ericifolia*		
6c	**Glen Forest**			
	Tall open-forest	*Eucalyptus deanei*	Diatremes	Isolated outcrops in Blue Mountains
6d	**Camden White Gum Forest**			
	Tall open-forest	*Eucalyptus benthamii*	Holocene alluvium	Confined to Nepean River at Bents Basin, Wallacia
9a	**Shale Cap Forest**			
	Open-forest	*Eucalyptus paniculata* *Eucalyptus notabilis*	Wianamatta Shale	Ridges along Bells road
9b	**Spotted Gum Forest**			
	Open-forest	*Eucalyptus maculata* *Eucalyptus moluccana*	Wianamatta Shale	On hills around Hoxton Park. Also around Werombi
9c	**Ironbark Forest**			
	Open-forest	*Eucalyptus crebra* *Eucalyptus fibrosa*	Wianamatta Shale	On shale remnants at Glenbrook
9d	**Shale/Gravel Transition Forest**			
	Open-forest	*Eucalyptus fibrosa* *Eucalyptus moluccana*	Wianamatta Shale/ Tertiary alluvium	On transition zone between these geological units

Map Unit	Structure	Main canopy species	Geology	Occurrence
9e	**Castlereagh Ironbark Forest** Open-forest	*Eucalyptus fibrosa*	Tertiary alluvium	Castlereagh area on clay soils
9f	**River-flat Forest** Open-forest	*Angophora subvelutina* *Eucalyptus amplifolia* *Eucalyptus tereticornis*	Holocene alluvium	Alluvial flood plains along Nepean-Hawkesbury River and major tributary creeks
9o	**Turpentine-Ironbark Forest** Open-forest	*Syncarpia glomulifera* *Eucalyptus paniculata*	Wianamatta Shale	Bankstown area
Sydney Sandstone Complex				
10ag	**Sydney Sandstone Gully Forest** i) Tall open-forest	*Eucalyptus deanei* or *Eucalyptus saligna* *Angophora floribunda* *Syncarpia glomulifera*	Hawkesbury Sandstone/ Narrabeen Group	Sheltered gullies Hillsides Sheltered gorges
	ii) Closed-forest	*Ceratopetalum apetalum* *Doryphora sassafras*		
	iii) Open-forest	*Eucalyptus piperita* *Angophora costata* +/- *Eucalyptus pilularis*	Hawkesbury Sandstone	Gullies, sheltered hillsides
10ar	**Sydney Sandstone Ridgetop Woodland** i) Low open-forest	*Eucalyptus sieberi* *Eucalyptus piperita*	Hawkesbury Sandstone	Ridgetops and plateaus >1200 mm pa

Map Unit	Structure	Main canopy species	Geology	Occurrence
10ar	**Sydney Sandstone Ridgetop Woodland (continued)**			
	ii) Woodland / Open woodland	*Eucalyptus gummifera* *Eucalyptus eximia* *Eucalyptus sparsifolia* *Angophora costata* *Angophora bakeri*	Hawkesbury Sandstone	Ridges and dry exposed hillsides
	iii) Open-forest / woodland	*Eucalyptus gummifera* *Angophora costata* *Eucalyptus notabilis* *Eucalyptus sparsifolia* *Eucalyptus punctata* *Syncarpia glomulifera*	Hawkesbury Sandstone with clay influence	Ridges
	iv) Open-scrub	*Angophora hispida*		Broad plateau surfaces
10c	**Grey Box Woodland**			
	Woodland	*Eucalyptus moluccana* *Eucalyptus tereticornis*	Wianamatta Shale	Flat to gently undulating basin of of Cumberland Plain. Clay soils
10d	**Grey Box-Ironbark Woodland**			
	Woodland	*Eucalyptus moluccana* *Eucalyptus tereticornis* *Eucalyptus crebra*	Wianamatta Shale	Undulating to hilly country on margins of Cumberland Plain. Clay soils
14a	**Castlereagh Scribbly Gum Woodland**			
	Low Woodland	*Eucalyptus sclerophylla* *Angophora bakeri*	Tertiary alluvium	Castlereagh-Londonderry and Holsworthy on sandy soils

Map Unit	Structure	Main canopy species	Geology	Occurrence
14b	**Agnes Banks Woodland** Low woodland / open scrub	*Eucalyptus sclerophylla* *Angophora bakeri* *Banksia serrata*	Tertiary alluvium	Confined to sand deposit at Agnes Banks
14c	**Swamp Woodland** Low woodland	*Eucalyptus parramattensis*	Tertiary alluvium	Poorly drained depressions and creek lines
21f	**Lower Blue Mountains Heath** Open-heath	*Eucalyptus stricta* *Allocasuarina nana*	Hawkesbury Sandstone	Dry, rocky ridge tops
26a	**Blue Mountains Sedge Swamps** Closed-sedgeland	*Gymnoschoenus sphaerocephalus* *Lepidosperma limicola* *Xyris ustulata* *Baeckea linifolia*	Hawkesbury Sandstone	Poorly-drained sites on plateaus
28a	**Freshwater Reed Swamps** Open-sedgeland	*Eleocharis sphacelata* *Juncus usitatus* *Persicaria* spp.	Holocene alluvium	Freshwater swamps
C	**Cleared**	These areas are generally the better agricultural soils along the river alluvial flats or on the Wianamatta Shale country. Small remnants of native vegetation too small to show on the map may occur here.		

Description of map units

A summary of the map units recognised on the Penrith sheet, their structural formations, main canopy species, geology and occurrence are given in Table 2. The map unit numbering system applies to the complete Sydney Region Vegetation Map Series. Missing numbers are those used for plant communities that are not found on the Penrith sheet. The vegetation map is located inside the back cover. The current work enlarges upon and updates a previous draft report (Benson 1981) and provisional maps (1981, 1985).

Map unit 4a - Estuarine Complex

Open-scrub:	***Avicennia marina***
Rushland/reedland:	***Juncus kraussii - Phragmites australis***
Low open-forest:	***Casuarina glauca***
Open-scrub:	***Melaleuca ericifolia***

Estuarine vegetation is confined mainly to the saline and brackish estuary of the Georges River downstream from Milperra Bridge. There is a variety of vegetation relating to the degree of flooding and the levels of salinity involved. The margin of the Georges River is fringed with mangroves, with both species that occur near Sydney, *Avicennia marina* and *Aegiceras corniculatum*, represented. They also extend into tributary creeks, in particular Deadmans Creek at Sandy Point and Williams Creek at Voyager Point. These mangroves are restricted to the intertidal zone. *Avicennia* is a ready coloniser of silt deposits, growing rapidly once established from water-dispersed seedlings. Studies in the Lane Cove River (McLoughlin 1985) indicate that *Avicennia* has responded to changes in sedimentation patterns in the river resulting from European settlement. This has generally caused increased silt deposits and in some places mangroves have increased their extent considerably, spreading further into the river. For the Georges River, Mitchell (1988) reports that over the last 50 years there has been a decrease in the area of saltmarsh communities and that generally mangroves have spread inland into saltmarsh areas. Local bank erosion and the loss of mangroves is occurring in some places possibly as a result of power boat wave damage (Ted Trainer pers. comm.).

Extensive saltmarsh with *Sarcocornia quinqueflora*, characteristic of saltmarsh further down the estuary and in particular at Towra Point, does not occur upstream of Mill Creek, probably because of different salinity or flooding frequencies. However, near the mouth of Williams Creek, behind the mangrove margin, is an estuarine sedgeland of *Juncus kraussii*, *Baumea juncea* and *Phragmites australis* and a number of saltmarsh species such as *Samolus repens*. An interesting record here is of *Wilsonia backhousei*, a rare saltmarsh plant previously known in the Sydney area only from Homebush Bay on the Parramatta River. This area would receive periodic brackish flooding.

Boundary relationships between mangroves and saltmarsh in the Georges River have been studied by Mitchell (1988). Boundary elevations of mangrove and saltmarsh decrease with distance from Botany Bay. These decreases appear to be more strongly related to river salinities than to tidal influences. Because of their decreased elevation and the increased tidal range further upstream, saltmarsh communities are tidally inundated more frequently up-river than in Botany Bay. Mitchell (1988) estimates that mangroves along the Georges River are tidally flooded between 17 and 60 times per month and saltmarsh 0 to 26 times.

Thickets or dense scrub of *Melaleuca ericifolia* 2–3 m high with some *Melaleuca linariifolia* and *Kunzea ambigua* (these last two species are normally asociated with non-brackish sites) occurs on sites with perhaps less saline influence but low lying and subject to occasional flooding. There is an extensive area of this scrub at Hammondville and it appears to have been common on the Milperra side of the Georges River in Kelso Park, though these areas have now been destroyed. Scrub in Deepwater Park is related but has less saline influence.

Zones of *Casuarina glauca* forest occur behind the mangroves along the Georges River and along Williams Creek. Low open-forest of *Casuarina glauca* is characteristic of estuaries but also occurs away from the coast in non-estuarine sites where there is some saline influence (for example in the Hunter Valley and on the Cumberland Plain). *Casuarina glauca* occurs between Liverpool and Camden, and south of Penrith where it is probably influenced by the salinity of the Wianamatta Shale groundwater (Figure 4). It occurs, for example, along creeks draining from shale areas such as Lansdowne Creek and Cabramatta Creek.

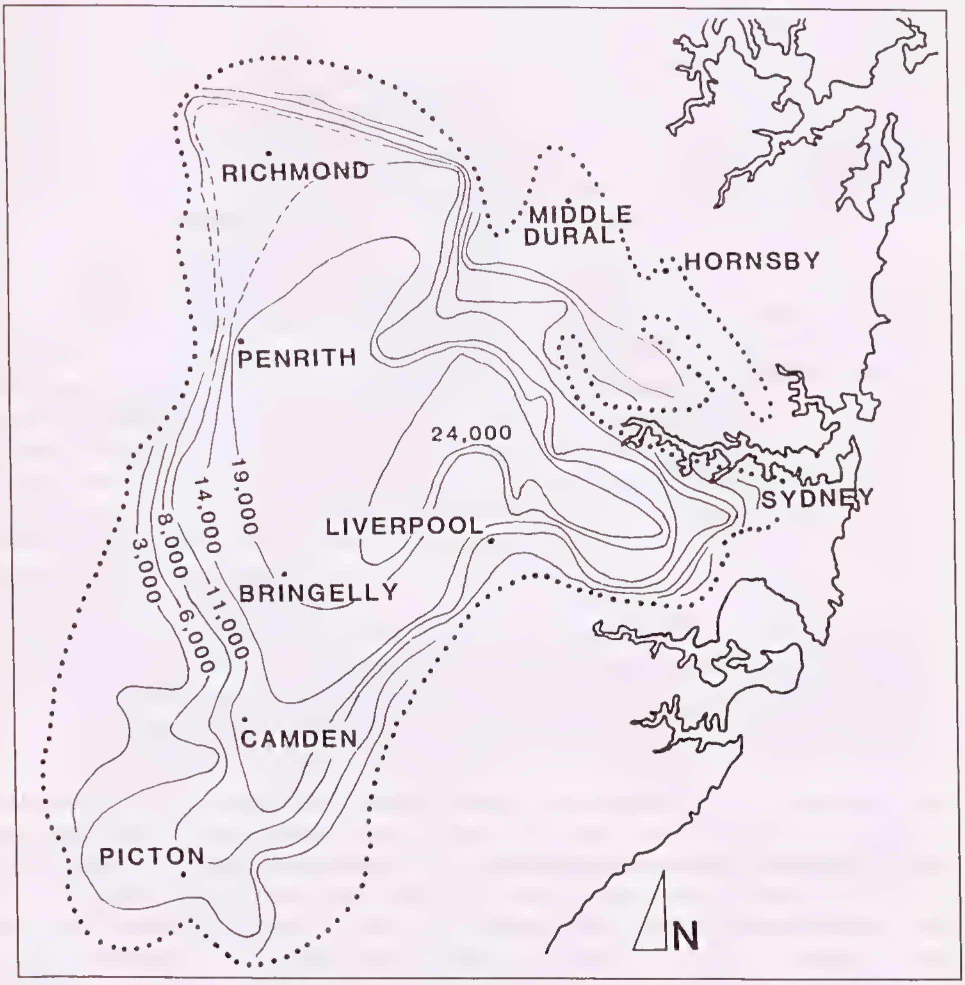


Figure 4. Soil salinity contours (ppm) for Wianamatta Shale groundwater (from Old 1942).

Swamp Oak Forest would have graded into the 'River Flat Forests' on the better drained alluvial flats and the 'Grey Box Woodlands' on nearby Wianamatta Shale hills. A stand of *Casuarina glauca* representing the intergrading form of the community is included within a proposed Nature Reserve at Kemps Creek.

Adam & Stricker (1989) report about 65 ha of estuarine wetland occurs along the Georges River in the Liverpool 1:25 000 map sheet area, with high naturalness ratings for Deadmans Creek, Williams Creek and Lieutenant Cantello Reserve.

Map unit 6c - Glen Forest

Tall open-forest: *Eucalyptus deanei*

In the lower Blue Mountains there are a number of small amphitheatre-shaped valleys formed from eroded volcanic intrusions or diatremes. Diatreme soils are variable, derived from the mixing of sandstone and basalt or breccia substrate as a result of the collapse of the sandstone wall-rocks into the volcanic intrusion and the subsequent deposition of sand eroded from the surrounding sandstone ridges (Crawford *et al.* 1980). They may have a sandy loam overlying a hardsetting clay loam forming red or yellow podzolic soils of the Volcanic Soil Landscape (Bannerman & Hazelton 1990). Such sites are more fertile than the surrounding Hawkesbury Sandstone countryside and have distinctive vegetation. This may be tall open-forest with trees of *Eucalyptus deanei* and *Syncarpia glomulifera*, an understorey with tall shrubs of *Notelaea longifolia, Acacia obtusifolia, Pultenaea flexilis, Hakea dactyloides* and *Polyscias sambucifolia*, climbers including *Smilax australis, Tylophora barbata, Eustrephus latifolius, Cissus hypoglauca, Hibbertia dentata, Clematis aristata* and *Comesperma volubile*, and ground cover dominated by *Calochlaena dubia, Dianella caerulea, Lomandra longifolia* and *Pteridium esculentum*, as at Murphys Glen on the adjacent Katoomba Sheet (Keith & Benson, 1988). On drier aspects there may be ironbarks, *Eucalyptus beyeriana* with a predominantly grassy understorey as at Machins Crater or on the Jack Evans Track near Erskine Creek. However, these diatremes often provided the best, though very localised, agricultural sites and were sought out and cleared or grazed by the early settlers. Tobys Glen and St Helena were grazed before becoming National Park. The ground cover is now dominated by ferns, particularly *Calochlaena dubia* and *Pteridium esculentum* and scramblers such as *Smilax* and *Cissus*, indicating a similar floristic composition to Murphys Glen, before stock grazing. St. Helena had 'well grassed forest land' at the turn of the century (Carne 1908). Where the soil fertility is lower, perhaps derived more from the surrounding rock than from volcanic breccia basalt, other species may occur. The Valley at Valley Heights, now mainly cleared, has remnant trees of *Eucalyptus amplifolia* and appears to have had a more grassy understorey. In William Cox's Journal of Road Construction over the Blue Mountains in 1814, mention is made of feeding and watering stock in the Valley, 'Nine and a half miles [from Emu Plains] grass and water in valley to right of road about a quarter of a mile' (quoted in Carne 1908). This indicates the importance of these grassy *oases* to the early settlers struggling through the poor sandstone country.

Small diatremes are also scattered across the Wianamatta Shale of the Cumberland Plain to the east (Crawford *et al.* 1980). These have all been cleared, and many quarried for crushed aggregate and there is very little evidence of their original flora, which would have been more like Valley Heights than Murphy Glen because of the lower rainfall and the clay influences from the surrounding Wianamatta Shale.

The large volcanic intrusion at Prospect forms a hill rather than an amphitheatre, but the vegetation here was cleared long before its flora had been recorded. It appears to have had *Eucalyptus moluccana* woodland similar to that of the surrounding Wianamatta Shale country (Phillips 1947). A number of uncommon ground species including *Ranunculus sessiliflorus, Scutellaria humilis* and possibly *Pultenaea microphylla* may be indicative of volcanic influence (Benson 1989). *Eucalyptus moluccana* is a common species on diatremes in the Putty area north of Windsor (Barwick 1903).

Map unit 6d - Camden White Gum Forest

Tall open-forest: *Eucalyptus benthamii*

A localised patch of tall open-forest restricted to a sand-bank and adjacent river bank of the Nepean River at Bents Basin, south of Wallacia, is dominated by large trees of *Eucalyptus benthamii*, Camden White Gum, originally up to 40 m in height, but altered by recent fire occurrences. Smaller trees include *Eucalyptus baueriana, E. elata* and *Angophora subvelutina*. The understorey has tall shrubs of *Acacia binervia* and *A. floribunda* with smaller native shrubs such as *Breynia oblongifolia* and *Hymenanthera dentata*. Ground cover is variable with patches of *Lomandra longifolia, Pteridium esculentum*. Introduced weed species, including *Cynodon dactylon, Olea africana, Tradescantia albiflora, Araujia hortorum* and *Ligustrum sinense* are common (Benson, Thomas & Burkitt 1990).

Eucalyptus benthamii is now a rare tree species but formerly occurred along the Nepean River flood-plain as far downstream as the Grose junction and along parts of the Coxs River and Kedumba Creek (Keith & Benson, 1988). Clearing has reduced its occurrence along the Nepean River to scattered trees, and Warragamba Dam has flooded much of its former occurrence in the Coxs valley. It is a long-lived tree (possibly up to 250 years) with periods of recruitment related to flooding and silt deposits, and death related to periods of frequent, or perhaps extreme fire events (Benson 1985). Whilst mature trees are able to recover from fire by suckering, small trees and newly growing suckers are vulnerable.

The occurrence of this relatively fire-sensitive species and the closely-related *E. viminalis* on alluvium along the floodplain of the Nepean may be attributable to particular soil and moisture requirements, but is also consistent with a fire regime, in the nearby Cumberland Plain woodland, of frequent low intensity burns confined to the grassy understorey, that failed to burn the more mesic vine and shrubby understoreys associated with the riverbanks, (such understorey can be inferred from early writers such as John Hunter; (see Benson & Howell 1990*a*), together with an occasional infrequent intense fire event under exceptional fire conditions.

Map unit 9a - Shale Cap Forest

Open-forest: *Eucalyptus notabilis - E. globoidea - Syncarpia glomulifera*

The most western remnants of Wianamatta Shale, reduced to cappings along the sandstone ridges are found along the Bells Line of Road from Kurrajong Heights to beyond Bilpin and near Springwood. Soils here are deep, relatively well drained clays, and originally carried tall open-forest on the wetter sites and open-forest on the drier sites and shallower margins of the shale. The tall open-forest was characterised by *Eucalyptus deanei* and *Syncarpia glomulifera* but has almost all been cleared for orchards and housing. Patches of the open-forest remain. This has tree species such as *Eucalyptus notabilis, E. globoidea, E. paniculata, E. cypellocarpa* and *Syncarpia glomulifera*. Common on the ecotone with the adjoining Hawkesbury Sandstone are *E. punctata* and *E. piperita*. The understorey has shrubs of *Acacia parramattensis* up to 4 m high and lower shrubs, commonly *Indigofera australis, Helichrysum elatum* and *H. diosmifolium*. A conspicuous component of the understorey are vines, *Smilax australis, Tylophora barbata, Kennedia rubicunda, Eustrephus latifolius* and *Glycine* spp. Grasses include *Entolasia marginata, Dichelachne rara, Microlaena stipoides* and *Echinopogon ovatus*, herbs include *Dichondra repens* and *Poranthera microphylla* and ferns, *Pteridium* *esculentum* and *Culcita dubia*. South of Springwood rainfall is lower and isolated shale residuals have the closely related Ironbark Forest, map unit 9c. Map units 9a and 9c are all part of the broadly defined Turpentine-Ironbark Forest of Benson & Howell (1990*a* & *b*).

Map unit 9b - Spotted Gum Forest

Open-forest: *Eucalyptus maculata - E. moluccana*

Open-forest of *Eucalyptus maculata*, the easily recognisable Spotted Gum, and *E. moluccana* is found on Wianamatta Shale on hilly country at Hoxton Park and Cecil Park west of Liverpool, and from Werombi southward to The Oaks. There is also an outlier at Appin. Rainfall ranges from 750 to 875 mm p.a. The hilly topography at Hoxton Park and the topographic position of the shale which overlies Hawkesbury Sandstone near Werombi, appears to improve the drainage of the normally damp Wianamatta Shale soils and may explain the occurrence of *Eucalyptus maculata*. A slightly higher rainfall at Werombi (1 000 mm p.a.) may also explain its distribution there.

Eucalyptus maculata made up nearly 60% of the total basal area and over 40% of the total density (Table 3). Usage for timber evidently began very early. A sale notice in the Sydney (Morning) Herald in November 1831 for a farm watered by Orphan School Creek, probably near Edensor Park or Cecil Park advertised 'Timber growing of valuable qualities, one of which (Spotted Gum) is now daily rising in repute for Staves of Casks ...'.

Other tree species are *E. fibrosa*, which occurs sporadically, *E. crebra*, which is particularly important around Werombi, *E. tereticornis* which is frequently important in depressions and *E. quadrangulata* which is found in a few moist, sheltered sites in the Werombi area. Occasional small tree species include *Allocasuarina torulosa*, *A. littoralis*, *Melaleuca decora* and *Acacia implexa*.

At Hoxton Park the understorey is mainly grasses with dense patches of shrubs 2 m high. These patches of shrubs are composed almost entirely of *Bursaria spinosa* (frequency 88% i.e. recorded at 88% of sites) accompanied occasionally by scattered

Table 3. Basal area and density of major tree species from 9 sites in *Eucalyptus maculata - E. moluccana* open-forest.

	Basal area (m²/ha)			Density (plants/ha)		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Eucalyptus maculata	14.2	4.1	59	225	97	43
E. moluccana	2.4	1.0	10	67	42	13
E. fibrosa	2.2	1.2	9	42	27	8
Total	24.0	3.1		516	135	

Other species contributing to total basal area - trees *Eucalyptus crebra, E. tereticornis, E. longifolia, E. punctata, E. quadrangulata*; small trees *Allocasuarina torulosa, A. littoralis, Melaleuca styphelioides, M. decora, Acacia implexa, A. parramattensis, Exocarpos cupressiformis*.

shrubs of *Dillwynia juniperina* and *Indigofera australis*. The normally prostrate twiner *Hardenbergia violacea* occurs as a 'shrub form' commonly up to 0.5 m high. Grass species are *Aristida vagans* (frequency 44%), *Entolasia marginata* (55%), *Eragrostis leptostachya* (44%), *Themeda australis* (66%) and *Echinopogon caespitosis* (55%). Common native herb species are *Brunoniella australis* (66%), *Dichondra repens* (77%), *Oxalis corniculata group* (44%), and *Pratia purpurascens* (55%).

At Werombi the understorey is much richer in shrub species, with *Breynia oblongifolia*, *Persoonia linearis*, *Allocasuarina torulosa*, *Acacia implexa* and *Clerodendrum tomentosum*. Twiners, *Geitonoplesium cymosum*, *Eustrephus latifolius*, *Stephania japonica* and *Clematis* species also occur here. Most of these species do not occur at Hoxton Park. At Appin, along the Appin-Campbelltown Road where there is a conspicuous outlier of Spotted Gum Forest, the understorey is much denser than at Hoxton Park and includes tall shrubs of *Acacia decurrens* and *A. implexa* and low shrubs of *Olearia viscidula* and *Lissanthe strigosa*.

Spotted Gum Forest is floristically similar to both the *E. moluccana* - *E. tereticornis* woodland and the *E. moluccana* - *E. crebra* woodland. It grades into the former on the lower slopes of hills around Hoxton Park and the latter on the lower slopes of the uplifted plateau west of Camden. The gradation is indistinct as many species are common to these communities. At some sites at Werombi it also grades into the Turpentine Forest. Again the transition is indistinct as many species overlap. *Eucalyptus maculata* also occurs along the Warringah Peninsula. However the Warringah Spotted Gum Forest is found in much wetter sites and has a much more mesic group of understorey species.

Most of the Cumberland Plain Spotted Gum Forest has been cleared, but in the past where small patches remained, the understorey usually remained as native pasture. Increasingly now, pasture improvement with exotic species is eliminating native species, which previously survived despite grazing. Much of the area has been subdivided for 'hobby farms', increasing the impact on natural remnants, but there are relatively undisturbed stands on some of the steeper slopes around Hoxton Park and smaller patches around Werombi, again on the steeper slopes. There is also a small stand on Water Board land on the southern side of Prospect Reservoir. Appin is also an important site for conservation as it provides a wildlife corridor between the Nepean and Georges River systems. No areas have been preserved in any Nature Reserve or National Parks and the small areas that exist in council reserves have generally been cleared of their native understorey and replaced with mown grass.

Map unit 9c - Ironbark Forest

Open-forest: *Eucalyptus crebra - Eucalyptus fibrosa*

This community is found on remnants of Wianamatta Shale along the Lapstone Monocline near Euroka, south of Glenbrook at Little Mountain, south of Bents Basin (Benson *et al.* 1990) and at Silverdale. The dominant trees are ironbarks, *Eucalyptus crebra*, *E. beyeriana* and *E. fibrosa*. At Little Mountain *E. punctata*, *E. eugenioides* and *Allocasuarina torulosa* also occur. There is an understorey of grasses and scattered shrubs of *Daviesia ulicifolia*. The vegetation contrasts with the surrounding Hawkesbury Sandstone vegetation but appears to differ somewhat from the vegetation on nearby Wianamatta Shale, along the Great Western Highway between Glenbrook and Springwood. Though much of the vegetation has been cleared for urban development, *Syncarpia glomulifera* appears to have been a major constituent of the vegetation near Springwood.

Map unit 9d - Shale/gravel Transition Forest

Open-forest: *Eucalyptus fibrosa - Eucalyptus moluccana*

This community occurs on the transitional zone between Wianamatta Shale and Tertiary alluvium (including gravel sediments), mainly between Penrith and Windsor. It contains a mixture of species found on these two areas. *Eucalyptus fibrosa*, one of the most common species on Tertiary alluvium, and *E. moluccana*, a common species on Wianamatta Shale, are the main dominants. Other tree species are *E. eugenioides* and *E. sclerophylla*. The understorey is dominated by low shrubs with a mixture of the hardier species from the Wianamatta Shale and Tertiary alluvium. *Bursaria spinosa, Daviesia ulicifolia, Dillwynia juniperina, Hardenbergia violacea, Exocarpos cupressiformis, Melaleuca nodosa* and *Acacia parramattensis* are the most common species. Small trees of *Melaleuca decora* are often conspicuous. A small patch of the community is protected in Longneck Lagoon Field Studies Centre at Pitt Town, and includes a small population of the rare shrub *Acacia pubescens*.

Map unit 9e - Castlereagh Ironbark Forest

Open-forest: *Eucalyptus fibrosa*

This unit, together with map units 14a, 14b, 14c, and the transitional 9d make up the Castlereagh Woodlands of Benson & Howell (1990*a* & *b*). Their conservation is one of the most critical issues for long-term planning for western Sydney.

On deep, well-drained reddish clay soils of the Tertiary alluvium around Castlereagh Ironbark open-forest is prominent. The best remaining stands are in Castlereagh State Forest where trees are up to 25 m high. *E. fibrosa* is the dominant tree species, generally forming pure stands, but may also be associated with *E. sideroxylon* and *E. crebra*, though these may be overlooked, since they are ironbarks with similar appearance to *E. fibrosa* and certainly much less common. In measured stands *E. fibrosa* made up about 43% of total basal area but only 21% of total plant density (Table 4). The bulk of density (69%) and 44% of total basal area is made up by *Melaleuca decora* which generally forms a small tree layer, (60–80% of the stems are less than 10 cm d.b.h.). Stems of *E. fibrosa* are now mostly 11–20 cm d.b.h. but much larger stems would once have been common.

An understorey of sclerophyllous shrubs up to 2 m high is generally associated with the pure stands of *E. fibrosa*. No particular species predominates, though the pea family Fabaceae is well represented. Shrub species which may be locally abundant

Table 4. Basal area and density of major tree species from 6 sites in *Eucalyptus fibrosa* open-forest.

	Basal area (m^2/ha)			Density (plants/ha)		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Melaleuca decora	5.1	1.7	44	470	183	69
Eualyptus fibrosa	4.9	1.3	43	145	31	21
Total	11.5	2.5		679	184	

Other species contributing to total basal area are the trees *Eucalyptus crebra, E. eugenioides, E. moluccana, E. sclerophylla, E. tereticornis* and the small trees *Angophora bakeri* and *Hakea sericea*.

are *Dillwynia tenuifolia, Dodonaea filifolia, Hakea sericea, Melaleuca nodosa, Mirbelia rubiifolia* and *Pultenaea villosa*. Less conspicuous, but frequent ground layer plants, are *Lissanthe strigosa, Cheilanthes sieberi, Brunoniella australis, Pratia purpurascens, Lepidosperma laterale* and *Dianella revoluta*. A number of species are of particular interest: *Micromyrtus minutiflora* (Myrtaceae); *Dillwynia tenuifolia*; *Pultenaea parviflora* (Fabaceae); *Grevillea juniperina* (Proteaceae); and *Dodonaea falcata* (Sapindaceae), including a number of local endemic species and forms (see Benson & McDougall 1991). For a species list for Castlereagh State Forest see Forestry Commission of NSW (1984).

This community usually grades into *E. sclerophylla - Angophora bakeri* woodland (map unit 14a) where the soil becomes more sandy, or into the *E. fibrosa - E. moluccana* open-forest (map unit 9d) on adjacent Wianamatta Shale.

The Tertiary alluvium provides very poor agricultural soils and there has been little serious agricultural usage. Recent increases in hobby farm and suburban development, and extensive gravel and clay extraction, are now leading to the clearing of much of the original vegetation. Good stands of *E. fibrosa* remain in Castlereagh State Forest, and although selective logging has altered the former open-forest structure, the floristic composition of the community is essentially undisturbed. It is highly desirable that the Forestry Commission manage this area as a conservation reserve. There is also an area of this community in Windsor Downs Nature Reserve though it is less diverse here than at Castlereagh. The *E. fibrosa* open-forest is a robust community, tolerant of most likely above-ground adjacent disturbances. Although rubbish dumping has been prolific in many areas, there is little sign of any major weed invasion problems. The shrub understorey may be reduced to a grassy understorey if an over-frequent fire regime is imposed.

Map unit 9f - River-flat Forest

Open-forest: *Angophora subvelutina - Eucalyptus amplifolia*

The floodplain of the Nepean–Hawkesbury River was the site of the first major intensive agriculture by the early european settlers. The River acquired two names as a result of being ‘discovered’ from two different directions; it is the Nepean above the Grose junction near Yarramundi, and the Hawkesbury below. The original distribution of vegetation related to floodplain topography. The levee banks along the river, and the back swamps beyond, produced a floodplain with tall open-forest on the well-drained crest and upper slopes of the levee bank adjacent to the river, and various sedge, rush and reed swamps in the depressions between the levee bank and sandstone cliffs (Benson 1974; Benson & Howell 1990*a* & *b*).

Between Richmond and Windsor, and on the levee banks along the Hawkesbury River downstream from Windsor, where the floodplain narrows, the levee bank forest was composed of trees over 30 m high. In 1791 John Hunter, standing on the banks of the Hawkesbury River near Richmond wrote, ‘the banks are high, and the soil a light sand, but producing fine straight timber’ (Hunter 1793). The largest trees were on the levee banks along the main channels of the river; smaller trees were associated with the poorly drained back-swamps. Referring to the lands of the Hawkesbury, Hunter and Shoalhaven Rivers, James Atkinson (1826) wrote ‘Most of the alluvial lands were originally forest; the timber was large, principally blue and flood gum, [he could be referring to *Eucalyptus tereticornis, E. saligna* or *E. deanei*] with an abundance of the tree known in the Colony by the appellation of the apple tree, [either *Angophora subvelutina* or *A. floribunda*] which is of little value’. Today, remnant trees along the floodplain indicate that *Eucalyptus tereticornis, E. deanei* and *Angophora floribunda* were originally the main forest tree species along the Hawkesbury.

The forest understorey appears to have been shrubby, and particularly dense. Evidently it made travelling difficult, as Hunter describes. 'The person who was charged with counting his paces, and setting objects to which they directed their march, had hitherto gone first; but the long sedge [*Gahnia*, *Lomandra longifolia*], the dead branches which had fallen from the trees, the nettles [*Urtica incisa*], and a weed resembling ivy which entangled the feet [*Smilax australis*?], made walking on, or near the banks of the river very fatiguing' (Hunter 1793).

There would have been a fringe of *Casuarina cunninghamiana* subsp. *cunninghamiana* along the water's edge and *Casuarina cunninghamiana* forest with occasional individuals of *Angophora subvelutina* was also found on islands of sand and gravel in the Nepean River between Penrith and Richmond. This has now been virtually destroyed by sand and gravel extraction, but remnant trees, up to 18 m high, indicate the original open-forest structure. Because of the scouring effects of floods, there would have been multistemmed shrubs of *Leptospermum polygalifolium* and *Tristaniopsis laurina*, which would have survived best on outcrops of boulders and gravel, now largely removed, that would have provided secure rooting. These species are still found in the Nepean Gorge upstream from Bents Basin. Other species would probably have been *Acacia binervia*, *Acacia floribunda*, *Goodenia ovata* and *Persicaria* species. A number of *Acacia* species, *A. floribunda*, *A. elata*, *A. binervia*, *A. ulicifolia*, *A. obtusifolia* and *A. parvipinnula* together with *Bossiaea rhombifolia*, *Pultenaea flexilis* and *Kennedia rubicunda* have been recorded colonising disturbed sand deposits at Penrith. With the exception of *Acacia binervia* and *A. floribunda*, mature plants of these species are rarely found in *Casuarina cunninghamiana* open-forest as young plants may be washed away by floodwaters before they can be properly established.

On sites sheltered by the steep-sided sandstone cliffs, particularly downstream from Sackville, there were pockets of low dense-forest with small trees and shrubs, many of 'rainforest type' species. They included small trees of *Acmena smithii*, *Trema aspera*, *Ficus coronata*, *Duboisia myoporoides*, *Backhousia myrtifolia* and *Tristaniopsis laurina*. Vines *Eustrephus latifolius*, *Geitonoplesium cymosum* and *Pandorea pandorana* twisted among the shrubs, while on the ground, clumps of ferns, commonly *Doodia aspera* and *Adiantum aethiopicum*, grew in the restricted light in the moist litter layer. Where moisture and shelter were less favourable, a more open shrub layer of *Leptospermum polygalifolium* and bipinnate wattles such as *Acacia parramattensis*, *A. decurrens* and *A. filicifolia* was present. Ground cover was *Pteridium esculentum* and native grasses. *Lomandra longifolia* was frequent, particularly on the river banks.

On the alluvial flats of the river upstream of Richmond, where the river becomes the Nepean, and tributary creeks, the predominance by *Eucalyptus tereticornis* gradually changed to predominance of *Eucalyptus amplifolia* subsp. *amplifolia* and *Angophora subvelutina*. Phillips (1947) described these species as occurring as far down the Hawkesbury River as Sackville, but Benson (1974) regarded the vegetation on the alluvial flats between Richmond and Sackville as *Eucalyptus tereticornis* tall open-forest. Because the original vegetation in this area has been almost completely destroyed, and the two communities were very similar, it is now impossible to give exact boundaries, though it is likely the two communities intergraded between Agnes Banks and Windsor.

The fringing forest along the Nepean River had some characteristic species. Peter Cunningham (1827) wrote 'The banks of the Cow-pasture river near Narellan are high, sandy, and clothed with goodly gum-trees, swamp oaks and scrubby brushwood'. The water's edge was probably lined with *Casuarina cunninghamiana* and occasional *Tristaniopsis laurina*. More localised tree species included *Eucalyptus viminalis*, *E. botryoides-saligna* intergrades, *E. elata*, *E. benthamii*, *E. baueriana* and *E. bosistoana*.

Eucalyptus viminalis and *E. botryoides-saligna* were found along the Nepean between Menangle and Camden, with *E. elata* common as far downstream as Wallacia. *Eucalyptus benthamii* occurred occasionally as far down as the junction with the Grose River although it is now restricted to the Cobbitty-Wallacia section. Of *Eucalyptus baueriana* Woolls (1880) wrote 'in the County of Cumberland on the banks of the Georges River, the Nepean, and the Hawkesbury, it is a tree of very moderate size ... I have found a tree of this species occasionally amongst forest-trees in the neighbourhood of Liverpool and Richmond but its proper habitat is near the banks of rivers and creeks. It does not occur as far as I have been able to ascertain, near Sydney or Parramatta'. It is a tree of slow growth and there are some large old specimens along the Nepean River at Camden Park. *Eucalyptus bosistoana* was probably always rare along the Nepean. A localised occurrence was also found at Milperra on the Georges River.

Though most of the forest on the Nepean River floodplain would have been of *Eucalyptus amplifolia* subsp. *amplifolia* and *Angophora subvelutina*, the closely related *Angophora floribunda*, appears to have replaced *Angophora subvelutina* along the smaller, slower-flowing Cumberland Plain creeks such as South, Kemps and Badgerys Creeks. There is also some intergradation between these two species.

The understorey of the floodplain forests would probably have had a discontinuous shrub layer of *Bursaria spinosa*. Paperbarks, *Melaleuca linariifolia*, *M. decora* and *M. styphelioides*, with a ground cover of *Juncus* species, chiefly *J. usitatus*, or sedges, were found in periodically waterlogged depressions. Along the river banks were denser shrubs; Peter Cunningham's 'scrubby brushwood' on the banks of the Nepean would have included *Acacia binervia*, *Tristaniopsis laurina*, *Backhousia myrtifolia*, *Acmena smithii*, *Acacia floribunda*, *Melia azedarach* and *Trema aspera*. Smaller shrubs would have included *Hymenanthera dentata*, *Phyllanthus gunnii*, *P. gasstroemii*, *P. similis*, *Goodenia ovata*, *Duboisia myoporoides*, *Calomeria amaranthoides*, and ground-cover plants, *Microlaena stipoides*, *Stipa verticillata*, *Geranium homeanum*, *Pratia purpurascens*, *Adiantum aethiopicum* and *Pellaea falcata*. *Phragmites australis* was common along the Nepean River near Penrith in 1860, and is still common there.

Where the river passes through sandstone gorges south of Penrith the alluvium vegetation is very restricted. A fringe of *Casuarina cunninghamiana* and *Angophora subvelutina* with *Eucalyptus deanei* on the lower slopes is common. The gorge above Bents Basin has woodland of *Tristaniopsis laurina* and *Casuarina cunninghamiana* (Benson *et al* 1990). On a boat trip from Penrith upstream to the Nepean Gorge, George Bennett (1860) observed amongst other things on the banks 'some Red Cedar-trees (*Cedrela Australis*) [now *Toona ciliata*], now becoming very rare to the colony; the largest was about 16 feet in height'. How widespread Red Cedar was originally on the floodplain is unknown though it was probably restricted to the banks of the Nepean and Hawkesbury. Bennett's trees were obviously young saplings and indeed there are still a couple of trees near the junction with Euroka Creek. No other Red Cedar trees appear to remain on the floodplain now, though *Melia azedarach*, White Cedar, a related native species, is still common along the Nepean and Hawkesbury river banks, and has been planted widely in the district.

On the smaller floodplains of the creeks, *Casuarina glauca* frequently formed dense stands, particularly where the watercourse was sluggish or intermittent. Clumps of small trees are often the result of its root-suckering nature. This species is characteristic of saline estuarine situations, often associated with mangrove and saltmarsh and its distribution may be related to the presence of the saline ground water found below much of the Wianamatta Shale country, particularly in the low lying central basin of the Cumberland Plain (Old 1942). Subsurface salt concentrations here are considered to be much higher than that suitable for crops and gardens and could be expected to affect native vegetation in low-lying sites. High salinities were noted in the early nineteenth century and are not necessarily a result of poor land use (Old 1942).

The River-flat Forests occupied some of the most fertile agricultural land in the Sydney area, land that has been farmed since the 1790s and most of the original vegetation has now been cleared. In most situations all that remains now are a few scattered old trees surrounded by improved pasture. As early as 1826, James Atkinson was writing, 'The greater part of the alluvial lands upon the Hawkesbury and Nepean have been cleared, and are under cultivation'. Old photos and paintings of the Hawkesbury in the late nineteenth century show an agricultural landscape similar to that of today.

Scattered remnants survive along the lower Hawkesbury below Windsor and tributary creeks such as Wheeny Creek. The main area mapped is at Agnes Banks on the Hawkesbury Campus of the University of Western Sydney, where a remnant of open-forest of *Angophora subvelutina* - *E. amplifolia* subsp. *amplifolia* associated with important wetland species survives. This area was recommended for preservation by Forster *et al.* (1977) and may become part of a joint conservation agreement between the National Parks & Wildlife Service and the University. No other examples of this type of forest in the area have been reserved. Small patches of open-forest with *E. tereticornis*, often surviving as quite large trees may be found in narrow valleys near Ebenezer and Cattai. At Kemps Creek, where *E. amplifolia* and *Casuarina glauca* forest are found along the creek, the latter appears to indicate salinity in the ground water. In other places *Casuarina glauca* forms pure stands, often as a result of its ability to root-sucker.

Along the Georges River was similar floodplain forest. Along Williams Creek near where it joins the Georges River are alluvial soils with floodplain forest with trees of *Angophora floribunda*, *Eucalyptus tereticornis*, *E. moluccana* and some less common *Eucalyptus baueriana*. This species was once common on the alluvium of the Georges River between Liverpool and Milperra, but has mostly been cleared. Where it remains, as at Deepwater Park, Milperra, it is now mown parkland where there are no chances of natural populations of seedlings establishing to replace it. Park management systems need to be appropriately changed to ensure its conservation.

Similarly small, often weed-infested, remnants occur sporadically along the Nepean–Hawkesbury River. Though often degraded these areas may contain local populations of the native species. The flora of these river-flats and floodplains disappeared very quickly after colonisation. As a result we have little idea of the interactions between native species, flood dispersal and the particular ecological adaptions that may have been involved. Rivers and creek systems are often recommended for protection as corridors for wildlife to allow propagule and genetic interchange, in otherwise developed environments. Such areas will need rehabilitation and the re-establishment of appropriate native vegetation if they are to be successful wildlife corridors. The protection of remaining native populations along creeks and rivers, particularly the Nepean-Hawkesbury will be essential if sources of appropriate material are to be available. The ephemeral nature of many native floodplain species means that their transitory habitats must be protected even when species are apparently absent.

Map unit 9o - Turpentine-Ironbark Forest

Open-forest: *Syncarpia glomulifera - Eucalyptus paniculata* subsp. *paniculata*

On the eastern edge of the map area near Bankstown are remnants of the Turpentine-Ironbark Forest originally found on moderate rainfall Wianamatta Shale soils further east. Tree species in Bankstown remnants include *Syncarpia glomulifera, Eucalyptus fibrosa* and *E. globoidea*. There is a mixing of species from the Cumberland Plain Woodlands - *Eucalyptus moluccana-E. tereticornis* dominated - of the drier shale areas the understorey contains species from both areas. There are also some interesting sites (for example, The Crest of Bankstown) with rainforest species such as *Euodia micrococca, Achronychia oblongifolia* and *Rhodamnia rubescens.*

Sydney Sandstone Complex (map units 10ag & 10ar)

This is the widespread vegetation complex found on the Hawkesbury Sandstone areas of the sheet. It occurs widely on the coastal plateaus up to 800 m elevation. It contains considerable local structural and floristic variation depending particularly on topographic position, local soil texture, drainage and aspect. Two broad subunits, have been recognised from aerial photos. These are a moist forest type, generally associated with sheltered hillsides and moist *gullies* (map unit 10ag) and a dry woodland type, generally associated with dry plateaus and *ridges* (map unit 10ar). The units have been used on the Katoomba and Wallerawang map sheets. On the lower Blue Mountains however this pattern is complicated by the presence of extensive areas of ridgetop with soils influenced by the Wianamatta Group and the Mittagong Formation, located stratigraphically between the lowest unit of the Wianamatta Group shale and the Hawkesbury Sandstone. Such areas occur for example on the Oakdale Tablelands, south of Glenbrook, Winmalee and near Bowen Mountain (Bannerman & Hazelton 1990). Soils here are yellow podzolics belonging to the Lucas Heights soil landscape, are deeper and more clayey than found on the Hawkesbury Sandstone elsewhere and support open forest vegetation. Because much of this area is within national parks and, because of its rugged terrain, difficult of access, much less field checking has been carried out in comparison with Cumberland Plain region.

Descriptions of most of the common Blue Mountains species are given in Baker *et al.* (1984, 1985) and a list of species occurring in sandstone areas on the margins of western Sydney is included in Benson & McDougall (1991).

Map unit 10ag - Sydney Sandstone Gully Forest

i) Tall open-forest: *Eucalyptus deanei* or *E. saligna - Angophora floribunda - Syncarpia glomulifera*

ii) Closed-forest: *Ceratopetalum apetalum - Doryphora sassafras*

iii) Open-forest: *Eucalyptus piperita - Angophora costata*

Sandstone Gully Forest is generally confined to gullies and sheltered hillsides, particularly on southern to eastern aspects. There are extensive areas around Kurrajong Heights and along creeks flowing southward to the Grose, apparently due to the high rainfall in the area (over 1 200 mm p.a.), the steep sheltered gorges along the tributaries of the Grose and enrichment from the shale soils on the ridges. It is less extensive south of the Grose River where annual rainfall is less than 1 000 mm.

Vegetation structure ranges from open-forest to tall open-forest and closed-forest. Floristic variation is considerable. Floristic groups may be recognised but there is considerable intergrading between these. Major gradients relate to increasing moisture, shelter and soil fertility. Closed-forest occurs where these three factors are combined to form favourable conditions. Major vegetation groupings are:

i) Tall open-forest: *Eucalyptus deanei* or *E. saligna - Angophora floribunda - Syncarpia glomulifera*

This vegetation is confined to valley floors or lower sheltered slopes where moisture, shelter and soil fertility are high. It occurs along major watercourses such as the Grose River, and creeks of the lower Blue Mountains as well as along Cattai and Little Cattai creeks near Maroota. *Eucalyptus deanei* and the closely related *E. saligna* rarely occur together. *Eucalyptus deanei* is more common in the lower Blue Mountains, *E. saligna* in the Cattai-Maroota area. Other tree species are *Angophora floribunda* and *Syncarpia glomulifera*. Associated species include shrubs, *Backhousia myrtifolia*, *Acacia elata* and *Allocasuarina torulosa*, scramblers, *Cissus hypoglauca*, *Cissus antarctica*, *Morinda jasminoides* and *Smilax australis* and ferns, *Calochlaena (Culcita) dubia*, *Doodia aspera* and *Pellaea falcata*.

ii) Closed-forest: *Ceratopetalum apetalum - Doryphora sassafras*

Small patches of closed-forest rainforest vegetation with *Livistona australis* occur on sheltered southerly aspects in the Kurrajong area around Mountain Lagoon and Wheeny Creek.

iii) Open-forest: *Eucalyptus piperita - Angophora costata*

This is the widespread vegetation of gullies and sheltered slopes on sandstone with annual rainfall generally greater than 1 000 mm.

The main trees are *Eucalyptus piperita* and *Angophora costata* but *Eucalyptus pilularis* may be locally abundant on more fertile sites. *Allocasuarina torulosa* is a common smaller tree. The understorey is dominated by a variety of shrubs, 0.5–2 m high, the main families being Proteaceae, Fabaceae and Myrtaceae. Common species include *Grevillea linearifolia*, *Pultenaea flexilis*, *Acacia terminalis*, single-stemmed form of *Hakea dactyloides* and *Persoonia linearis*. There is a distinctive shrub flora along creeks, including the species *Tristaniopsis laurina*, *Backhousia myrtifolia*, *Ceratopetalum apetalum* and *Callicoma serratifolia*.

Sandstone Gully Forest of *Eucalyptus piperita* and *Angophora costata* together with *E. pilularis* occurs on sheltered hillsides in the north-eastern corner of the map sheet (Benson & Howell 1990*a*). On the lower Blue Mountains there are extensive areas of open-forest around Kurrajong Heights and along creeks flowing southward to the Grose. These are responding to the high rainfall in the area (over 1 200 mm), the deep sheltered gorges along the tributaries of the Grose and enrichment from the shale soil on the ridges. *Eucalyptus sieberi* probably indicates well-drained but poorer soils. Rodd (1987) describes open-forest of *Eucalyptus piperita*, *E. sieberi* and *Angophora costata* with some *E. cypellocarpa* or *E. agglomerata* as occurring over large areas of drier or less fertile (in comparison with the basalt soils) lower slopes of Mount Tomah to the west of the map sheet area and a little higher in elevation, but similar vegetation occurs on sandstone hillsides near Bilpin and Kurrajong Heights.

On the lower Blue Mountains south of the Grose, rainfall tends to be lower and gully vegetation less mesic. Rainfall at Springwood is just over 1 000 mm p.a. and at Warragamba it is 970 mm p.a. Sandstone Gully forest at Bents Basin includes *Eucalyptus pilularis* and *Syncarpia glomulifera* with *Ceratopetalum apetalum* and *Backhousia myrtifolia* along perennial creek lines (Benson, Thomas & Burkitt 1990). There is a sparse shrub understorey consisting mainly of *Bossiaea rhombifolia*, *Persoonia linearis* and *Leptospermum trinervium (attenuatum)*.

Map unit 10ar - Sydney Sandstone Ridgetop Woodland

i) Low open-forest: ***Eucalyptus sieberi - Eucalyptus piperita***

ii)Woodland/
open-woodland: ***Eucalyptus gummifera - Eucalyptus eximia - Angophora costata - Angophora bakeri - Eucalyptus sparsifolia***

iii) Open-forest/
woodland: ***Eucalyptus gummifera - Angophora costata - E. notabilis - E. sparsifolia - E. punctata - Syncarpia glomulifera***

iv) Open - scrub: ***Angophora hispida*** (see also Map unit 21f)

Like the Sandstone Gully Forest, the Sandstone Ridgetop Woodland is considerably variable both structurally and floristically. Structure ranges from open-forest to woodland, open-woodland, low woodland, scrub and heath. Major gradients are apparently related to rainfall and soil texture, in particular to sand and clay content. These also influence drainage conditions and add local variation to broader trends. Some tree species occur over a wide range of conditions - *Angophora costata, Eucalyptus gummifera, E. sparsifolia, E. piperita* for example are ubiquitous. Other species are more likely to indicate particular conditions - *Syncarpia glomulifera* and *Eucalyptus punctata* may indicate clay soil influence, *Angophora bakeri* and *Eucalyptus eximia*, low rainfall well drained sites, *E. sclerophylla* - damp shallow soils, *Eucalyptus sieberi*- well drained sites with higher rainfall.

Ridge and plateau vegetation has a rich, sclerophyllous, shrubby understorey with species of Proteaceae, Fabaceae, Epacridaceae and Myrtaceae. Shrub and ground cover species may be better indicators of local conditions though again there are very widespread species such as *Leptospermum trinervium, Lambertia formosa* and *Isopogon anemonifolius*. Some major species groupings can be recognised and related in particular to soil and rainfall conditions but there is considerable intergradation and local variation within them. They do however serve as a guide for understanding vegetation and landform. Detailed studies of plant response to soil and rainfall gradients are needed to confirm these exploratory hypotheses.

i) Low open-forest: *Eucalyptus sieberi - Eucalyptus piperita*

Rodd (1987) describes low open-forest with *Eucalyptus piperita, E. sieberi, E. burgessiana* and *E. stricta* in various combinations together with scattered occurrences of *E. oblonga* and *Angophora costata* for the tops of sandstone spurs around Mount Tomah. Soils are mostly very shallow, associated with rock ledges, often poorly drained and highly infertile. Similar vegetation occurs widely north of the Grose River, but south of the Grose *Eucalyptus sieberi*, in particular, is less common. This probably relates to the higher annual rainfall in the Kurrajong area (above 1 200 mm p.a.) compared with elsewhere in the lower Blue Mountains. *Eucalyptus sieberi* occurs again on the coast where rainfall is again higher. Common shrub species listed by Rodd include *Banksia ericifolia, B. spinulosa, Lambertia formosa, Isopogon anemonifolius, Hakea dactyloides, Leptospermum trinervium (attenuatum), L. polygalifolium (flavescens), Platysace linearifolia, P. lanceolata, Dillwynia floribunda* and *Epacris microphylla*.

ii) Woodland/ open-woodland: *Eucalyptus gummifera - Eucalyptus eximia - Angophora costata - Angophora bakeri - Eucalyptus sparsifolia*

This vegetation is found on dry hillsides and ridges on the lower Blue Mountains generally south of the Grose River. These areas appear to be drier than those with *E. sieberi - E. piperita* low open-forest with an annual rainfall of less than 1 000 mm per annum. Soils are earthy sands or yellow earths with a depth of 50–100 cm belonging to the Faulconbridge, Hawkesbury and Gymea soil landscapes (Bannerman & Hazelton 1990). Understorey is shrubby with species such as *Leptospermum trinervium, Hakea sericea, Grevillea buxifolia, Baeckea diosmifolia, Leucopogon muticus* and *Persoonia levis.* Patches of mallee eucalypts, including the restricted species *Eucalyptus burgessiana* and *E. multicaulis,* are frequent along ridges running north from Springwood, and with *E. consideniana* along the Woodford Range.

Sandstone country drained by Cattai, O'Haras and Little Cattai Creeks in the north-eastern corner of the map sheet has woodland with *Eucalyptus haemastoma, E. sclerophylla, E. gummifera, E. eximia, E. punctata, Angophora costata* and *A. bakeri.* Sclerophyllous understorey shrubs include species of *Banksia, Grevillea, Hakea, Boronia, Leptospermum* and *Pultenaea* (Benson & Howell 1990*a*).

In the south-east corner of the sheet around East Hills and Holsworthy woodland trees include *Eucalyptus sclerophylla, E. punctata, E. piperita* and *Angophora bakeri.* The understorey has a variety of shrub species including *Acacia terminalis, Grevillea sericea, Banksia spinulosa* var. *spinulosa* and *Philotheca salsolifolia.*

iii) Open-forest/ woodland: *Eucalyptus gummifera - Angophora costata - Eucalyptus notabilis - Eucalyptus sparsifolia - Eucalyptus punctata - Syncarpia glomulifera*

This vegetation is found on Hawkesbury Sandstone on sites with a clay influence. In the lower Blue Mountains these soils are found on ridgetops and have developed from the Mittagong Formation at the stratigraphic junction between the Wianamatta Shale and the Hawkesbury Sandstone. Soils are yellow podzolics and belong to the Lucas Heights soil landscape.

Other sites with a clay influence may be due to shale lenses in the Hawkesbury Sandstone or residual areas of Wianamatta Shale. The latter areas generally have distinctive Ironbark Forest (mapped as unit 9c).

Species such as *Syncarpia* are generally good indicators of clay soils, though other tree species may occur in a wide range of sites. Understorey species tend to be better site indicators and species such as *Bossiaea obcordata, Grevillea mucronulata, Cyathochaeta diandra* and *Entolasia stricta* are characteristic.

Woodland communities at Bents Basin are influenced by shale residuals (Benson *et al.* 1990) and a variety of species occur including *Eucalyptus gummifera, E. eximia, Angophora costata, E. pilularis* and *E. punctata. Lambertia formosa, Persoonia linearis, Leptospermum trinervium* and *Leucopogon muticus* are common shrubs.

iv) Open - scrub: *Angophora hispida* (see also Map unit 21f)

Within the ridge-top woodland, particularly shallow soils support open-scrub with *Angophora hispida;* patches are found particularly around Annangrove and Maroota. Localised areas of open-heath, open-scrub and sedgeland are mapped separately as communities 21f and 26a respectively.

Map unit 10c - Grey Box Woodland

Woodland: *Eucalyptus moluccana - Eucalyptus tereticornis*

Grey Box Woodland is found on the flat to gently undulating country that makes up much of the dry central Cumberland Plain core, between Parramatta and Penrith with a rainfall of 700–800 mm p.a. It is part of the *Eucalyptus hemiphloia* [=*moluccana*] - *E. tereticornis* association of Pidgeon (1941) and Phillips (1947) which has been here divided into a number of units, the most important being the Grey Box Woodland (map unit 10c) and the Grey-Box-Ironbark Woodland (map unit 10d). This unit and the following map unit 10d, together with Spotted Gum Forest make up the Cumberland Plain Woodland of Benson & Howell (1990*a* & *b*).

Governor Arthur Phillip (1789) described country to the west of Parramatta in April 1788. 'The country through which they travelled was singularly fine, level, or rising in small hills of a very pleasing and picturesque appearance. The soil excellent, except in a few small spots where it was stony. The trees growing at a distance of from 20 to 40 feet [6–12 m] from each other, and in general entirely free from brushwood, which was confined to the stony and barren spots'. This description of the Grey Box Woodland indicates it to have originally been an open community of park-like appearance, with well spaced, large, spreading trees and an understorey mainly of tussock grasses and herbs, and localised patches of denser scrub. The 'stony and barren spots' with 'brushwood' are probably ironstone residuals or gullies in Hawkesbury Sandstone which would have had a dry shrubby understorey.

John White (1790), on the same expedition wrote 'The country here about [near Greystanes Hill] was pleasant to the eye, well wooded, and covered with long sour grass, growing in tufts. At the bottom of this valley or flat, we crossed another watercourse, and ascended a hill, where the wood was so very thick as to obstruct our view'.

Similarly, John Hunter (1793) writes 'The country about Rose Hill, [near Parramatta], which I have formerly mentioned as requiring not much labour in clearing, from its being covered only with lofty, open woods, without any underwood, and which I then observed ran to the westward about 20 miles, [32 km] has since been travelled over by several gentlemen, who admit that that kind of country does extend near the distance above-mentioned to the westward, but in a north and south direction, it does not extend more than 3 or 4 miles, [5–6 km] when you come again into barren rocky land wholly unfit for cultivation ...'. This latter country is probably on Hawkesbury Sandstone.

In describing the central basin of the Cumberland Plain, James Atkinson (1826) writes 'In the county of Cumberland, one immense tract of forest land extends, with little interruption, from below Windsor on the Hawkesbury, to Appin, a distance of 50 miles [80 km]; large portions of this are cleared and under cultivation, and of the remainder that is still in a state of nature, a great part is capable of much improvement. The whole of this tract, and indeed all the forest in this county, was thick forest land, covered with very heavy timber, chiefly iron and stringy bark, box, blue and other gums, and mahogany'.

All these writers give the impression of open, though in some places locally dense stands of trees forming a woodland (*sensu* Specht 1970) with a grassy understorey. The nature of the understorey is clearly indicated by Atkinson who defines his use of the word 'forest'. 'It is, however, always to be understood that forest means land more or less furnished with timber trees, and invariably covered with grass underneath, and destitute of underwood'.

Estimates of canopy height in remnant stands ranged from 10 to 20m and canopy cover ranges from 10 to 73%. These figures include both woodland and open-forest formations, the latter structure being found in stands with vigorous regeneration. Most sites had been disturbed in the past and except for large, old trees which were either multistemmed and showed evidence that stems had been cut, or appeared to be sapling regrowth. From Governor Phillip's (1789) estimates of tree spacing 'from twenty to forty feet from each other', a range of tree density from 68 trees/ha to 272 trees/ha can be calculated. The present mean tree density (378 plants/ha) (Table 5) is higher as a result of the denser regrowth following clearing or disturbance. The sites with low tree densities, sites 90 (3 trees), 73 (4 trees), 80 (5 trees) and 74 (5 trees) generally have larger trees.

Table 5. Basal area and density of major tree species from 31 sites in the *Eucalyptus moluccana - E. tereticornis* woodland.

	Basal area (m^2/ha)			**Density (plants/ha)**		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Eucalyptus moluccana	5.5	1.1	39	113	21	30
E. tereticornis	4.5	1.3	32	125	29	33
E. eugenioides	1.0	0.2	7	13	7	3
Melaleuca decora	0.9	0.4	6	53	27	14
Total	14.4	1.5		378		

Other species contributing to total basal area - trees *Angophora subvelutina, Eucalyptus amplifolia* subsp.*amplifolia, E. fibrosa, E. longifolia*; small trees *Acacia decurrens, A. parramattensis, Angophora bakeri, Casuarina glauca, Allocasuarina littoralis, Melaleuca styphelioides.*

The main tree species, *Eucalyptus moluccana*, Grey Box and *E. tereticornis*, Forest Red Gum, today make up over 70% of the total basal area and 60% of the total stem density of sites examined (Table 5). The total basal areas and stem densities of the two species are about equal but they occur together in varying proportions. *E. moluccana* appears to favour the higher topographic situations of upper slopes and rises and *E. tereticornis* favours lower slopes and depressions. There was a negative correlation ($r = - 0.43$, 23 d.f. $p < 0.05$) between them based on basal area data.

Less common tree species are *E. fibrosa*, which is generally found near the edge of the mapped community, perhaps on sandier sites, *E. longifolia* which occurs sporadically, its main occurrence being in the Grey Box-Ironbark Forest further east, and *E. amplifolia* and *Angophora subvelutina* which are confined to creek channels or poorly-drained sites. *E. amplifolia* replaces the very closely related species *E. tereticornis* on such sites. Small trees of *Casuarina glauca* and *Melaleuca decora* are found in similar impeded drainage situations.

The understorey may be shrubby or grassy depending on disturbance or grazing intensity. Evidently there was considerable local variation in the type of understorey even in the earliest days. John Macarthur wrote to Governor King in 1804 (Historical Records of Australia 5, 583) concerning the pasture value of land in the vicinity of Prospect. 'I have not seen any unappropriated range of 5,000 acres [2,000 ha] that contains 500 acres [200 ha] of dry pasture on which I should think it safe to feed sheep ... I carefully examined a tract from near George's River to the Nepean, and from thence to the South Creek and Prospect Hill, but entirely without success. Almost the whole is of that wet kind which has been found so fatal to sheep, or is covered with scrubby brushwood'. The 'wet kind' of land probably caused sheep losses through liver fluke or foot rot and would have been partly covered with stands of *Casuarina glauca* or *Eucalyptus amplifolia* subsp *amplifolia*, found on poorly-drained land. 'Scrubby brushwood' here may refer to the stands of *Melaleuca decora* which are still common west of Liverpool.

The main shrub species now is *Bursaria spinosa* which grows in both dense clumps or as scattered individuals. It was found at every site and densities, recorded from a limited number of sites, ranged from 100 to 1 000 plants/ha. Density may be related to grazing or burning patterns as undisturbed sites carry the densest stands. In 1817 the botanist Allan Cunningham, on visiting the farm of a friend near Liverpool wrote, 'Like other farms in the neighbourhood it is overrun with the *Bursaria spinosa* now in fruit' (Lee 1925). Whether there was an increase in the abundance of *Bursaria spinosa* occurring at the time as a result of changes in grazing, cultivation, or fire management is not clear but the species has remained abundant.

Only one other shrub species, *Dillwynia juniperina*, occurred at more than 25% of the sampling sites though this, and the less common shrubs *Daviesia ulicifolia* and *Indigofera australis*, may have high densities on particular sites. Other less common shrubs, *Acacia parramattensis*, *A. decurrens* and *A. implexa* generally have much lower local densities.

European settlement both increased and decreased fire frequencies depending on the locality. James Atkinson wrote in 1826: 'In the unoccupied districts in the interior, and also in those tracts that are only used for the purposes of grazing, the grass in winter becomes withered by the frosts, and assumes the appearance of bad coloured hay; in this state it is refused by the cattle; and as it impedes the growth of young grass, the common practice is to set fire to it. The Natives also pursue the same system setting fire to the thick brushes and old grass every summer; the young herbage that springs up in these places, is sure to attract the kangaroos and other game; and the horned cattle are also very fond of feeding upon this *burnt ground*, as it is termed in the colony; ... In dry seasons these periodical burnings sometimes assumes a truly awful appearance, the country seems on fire in all directions, and if the weather is calm, is enveloped in dense smoke'. Many of the shrub species regenerate rapidly after a fire and their local abundance may have been increased by the early settlers' use of fire for clearing followed by longer periods of protection from fire. The small remnants of bush surviving now are probably only infrequently burnt.

Phillips (1947) described *Themeda australis* as the typical species of undisturbed sites together with *Dichelachne micrantha* and *Sorghum leiocladum* but that these were readily lost by overgrazing leaving *Bothriochloa macra*, *Chloris truncata*, *Eragrostis leptostachya* and *Danthonia* species predominating. Under trees *Bothriochloa* and *Chloris* were replaced by *Aristida vagans*, *A. ramosa* and *Microlaena stipoides*. Phillip's work was done at a time when the Cumberland Plain vegetation was heavily grazed. Recent patterns of subdivision and changing urban and rural development often leave areas temporarily ungrazed, and many sites recorded during the present survey were on areas no longer grazed. Species recorded were mainly perennial grasses particularly *Themeda australis* (recorded on 87% of quadrats) *Eragrostis leptostachya* (32%), *Aristida vagans* (39%) and *A. ramosa* (26%). Small herbs were also common, particularly *Dichondra repens* (90% of quadrats), *Brunoniella australis* (87%), *Lomandra filiformis* (35%), *Dianella laevis* (39%), *Oxalis corniculata group* (74%) and *Cheilanthes sieberi* (55%). Many of these sites have been subsequently destroyed.

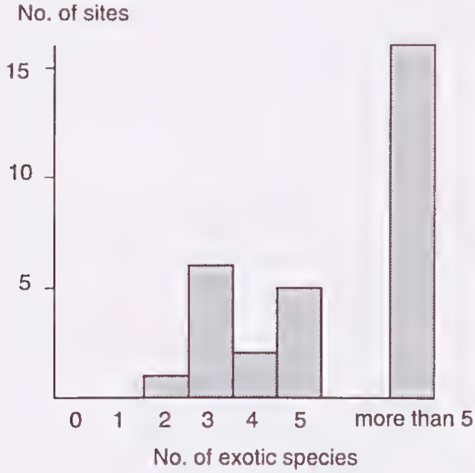
Allan Cunningham mentions some of the species between Parramatta and Liverpool in 1818. 'In my route towards Liverpool, on a line of road about 9 miles [14 km], bounded by open forest-land and confined dense brush, many interesting (already described) plants were in flower, among which I gathered the following *Pomaderris* *betulina*, flowers panicled axillary and terminal. *Diosmeoe*, habit of *Correa*, a shrub with white flowers; also a genus of this order allied to *Eriostemon*, stamina smooth, leaves oblong, narrow obtuse. *Dampiera undulata*, a suffruticose blue flowering plant [possibly *Dampiera stricta*]. *Colletia* sp., a small tufted leaved, spinous shrub, suspected to be allied to *Cryptandra* [possibly *Cryptandra amara* or *spinescens*] is now frequent, in flower and fruit, in the vicinity of the town of Liverpool. In moist situations I gathered a small plant of the order Gentianaceae, *Erythraea australis* [*Centaurium spicatum*]. To the southward of Liverpool the country is an open forest-land of common *Eucalypti*, in which *Exocarpus cupressiformis*, and the papilionaceous tree *Jacksonia scoparia*, at this period laden with yellow flowers, are very conspicuous. *Pimelea spicata* and *P. glauca* of Mr Brown; a small *Daviesia* with cordate leaves (*D. squarrosa*, Smith); with a *Helichrysum*, allied to *H. papillosum* and prevalent in this description of country ... In situations on the roadside, more or less subject to inundation, a delicate tufted *Lobelia* (*L. inundata*) is in flower, and *Ruellia australis* [*Brunoniella australis*] is common in grassy dry spots, decorating our path throughout this days route' (Lee 1925).

Cunningham's references to the Pimeleas are interesting. *Pimelea spicata* is now extremely rare, and now only known from a few locations in western Sydney, though it was formerly more common. Similarly *Pimelea glauca* has only been recorded from a few places in the Sydney area including Cunningham's specimen, collected 'near Liverpool' in 1818; this was presumably on the journey described above and is held

Table 6. a) Number of native exotic species recorded from sites in *Eucalyptus moluccana–E. tereticornis* woodland.

	range	mean	s.e.m.
Total number of species / site	15–46	32.7	1.3
Number of native species / site	12–41	25.8	1.2
Number of exotic species / site	2–19	6.9	0.7
Total number of native species recorded	188		
Total number of exotic species recorded	46		

b) Frequency of exotic species



at the National Herbarium of New South Wales. Perhaps Cunningham's *Pimelea* specimens from Liverpool indicate original Cumberland Plain species that were quickly exterminated by the settlers' stock grazing or other associated land use change?

Land use changes have also allowed exotic species to establish. During this study between 2 and 19 exotic species were recorded on every site (Table 6). More than half the sites had more than 5 exotic species, the most common species being *Hypochaeris radicata*, *Conyza floribunda*, *Plantago lanceolata* and *Paspalum dilatatum* (Table 7).

Though much of the vegetation that now remains has been heavily disturbed, some remnants still carry quite a large number of native species. Though a number of recommendations have been made, no areas have been preserved in any national park or nature reserve. A good example at Kemps Creek is presently being considered. Some areas have been included in council reserves but in many of these the understorey has been mowed or replaced with exotic Kikuyu grass, *Pennisetum clandestinum*.

Table 7. Exotic species recorded in *Eucalyptus moluccana* - *E. tereticornis* woodland.

	% frequency
APIACEAE	
Apium tenuifolium	11
ASCLEPIADACEAE	
Araujia hortorum	38
Gomphocarpus fruticosus	11
ASTERACEAE	
Aster subulatus	11
Bidens pilosa	50
B. subalternans	4
Circium vulgare	38
Conyza floribunda	84
Gnaphalium purpureum	4
G. spicatum	4
Hypochaeris glabra	4
H. radicata	92
Leontodon leysseri	23
Taraxacum officinale	8
CACTACEAE	
Opuntia stricta	4
CRASSULACEAE	
Kalanchoe tubiflora	4
FABACEAE	
Lotus angustissimus	8
IRIDACEAE	
Romulea rosea	11
ASPARAGACEAE	
Asparagus densiflorus	4
A. officinalis	8
Myrsiphyllum asparagoides	8
MALVACEAE	
Modiola caroliniana	11
OLEACEAE	
Ligustrum sinense	11
Olea europea subsp. africana	19
PLANTAGINACEAE	
Plantago lanceolata	80
POACEAE	
Bromus catharticus	4
Cynodon dactylon	11
Digitaria violascens	4
Paspalum dilatatum	76
P. urvillei	4
Pennisetum clandestinum	4
Setaria geniculata	42
Sporobolus africana	27
POLYGONACEAE	
Rumex crispus	4
PRIMULACEAE	
Anagallis arvensis	8
ROSACEAE	
Rosa rubiginosa	4
Rubus vulgaris	4
RUBIACEAE	
Richardia stellaris	19
SOLANACEAE	
Lycium ferocissimum	11
Solanum mauritianum	4
S. nigrum	4
S. pseudocapsicum	4
S. sodomaeum	4
VERBENACEAE	
Lantana camara	8
Verbena officinalis	11

Table 8. The Grose Vale 'limestone flora' recorded by Carne (1908) indicating species recorded by Bill May in 1984 (pers. comm.). Soil types indicated by Carne, S = shale, I = intermediate, L = limestone; + = present in 1984. (Family names minus -aceae in brackets).

DICOTYLEDONS		
Abutilon oxycarpum (Malv.)	S	+
Acacia decurrens (Fab.)	S	+
Acacia longifolia (Fab.)	S	+
Acaena novae-zelandii (Ros.)	S	
Acaena ovina (Ros.)	S	
Acmena smithii (Myrt.)	L	
Alectryon subcinereus (Sapind.)	L	+
Alphitonia excelsa (Rhamn.)	L	+
Aphanopetalum resinosum (Cunoni.)	I	+
Brachychiton populneus (Sterculi.)	I	+
Breynia oblongifolia (Euphorbi.)	I	+
Bursaria spinosa (Pittospor.)	S	+
Callistemon salignus (Myrt.)	S	+
Calotis lappulacea (Aster.)	S	
Cassia odorata (Fab.)	L	+
Cassine australis (Celastr.)	L	+
Cayratia clematidea (Vit.)	L	+
Cissus antarctica (Vit.)	L	+
Cissus hypoglauca (Vit.)	L	+
Citriobatus pauciflorus (Pittospor.)	L	+
Clematis aristata (Ranuncul.)	S	
Clematis glycinoides (Ranuncul.)	S	
Clerodendrum tomentosum (Verben.)	I	+
Croton verreauxii (Euphorbi.)	I	+
Cuttsia viburnea (Escalloni.)	L	
Daucus glochidiatus (Api.)	S	
Desmodium brachypodium (Fab.)	S	
Dichondra repens (Convolvul.)	S	
Diospyros australis (Eben.)	L	
Dodonaea viscosa (Sapind.)	S	+
Ehretia acuminata (Boragin.)	L	+
Einadia trigonon (Chenopodi.)	S	+
Endiandra ? (Laur.)	L	
Sambucus australasica (Caprifoli.)	L	
Santalum obtusifolium (Santal.)	L	
Sarcomelicope simplicifolia (Rut.)	L	
Sarcopetalum harveyanum (Menisperm.)	L	+
Senecio glomeratus (Aster.)	S	
Sigesbeckia orientalis (Aster.)	S	
Solanum prinophyllum (Solan.)	S	
Solanum stelligerum (Solan.)	S	+
Tasmannia insipida (Winter.)	L	
Trema aspera (Ulm.)	I	+
Toona ciliata (australis) (Meli.)	L	+
Urtica incisa (Urtic.)	S	
Vittadinia tenuissima (Aster.)	S	
Wahlenbergia gracilis (Campanul.)	S	+
MONOCOTYLEDONS		
Aristida vagans (Po.)	S	
Bothriochloa decipiens (Po.)	S	
Carex appressa (Cyper.)	S	
Carex longebrachiata (Cyper.)	S	
Cenchrus caliculatus (Po.)	L	
Commelina cyanea (Commelin.)	S	
Cymbopogon refractus (Po.)	S	
Cynodon dactylon (Po.)	S	
Danthonia pilosa (Po.)	S	
Dianella laevis (Dianell.)	S	+
Dichanthium sericeum (Po.)	S	
Dichelacne sciurea (Po.)	S	
Echinopogon ovatus (Po.)	S	
Eragrostis leptostachya (Po.)	S	
Eustrephus latifolius (Philesi.)	S	+
Gahnia aspera (Cyper.)	S	
Gahnia melanocarpa (Cyper.)	S	
Geitonoplesium cymosum (Philesi.)	S	+
Juncus ?usitatus (Junc.)	S	

Epilobium billardierianum (Onagr.)	S
Eucalyptus moluccana (Myrt.)	S +
Eucalyptus tereticornis (Myrt.)	S +
Eupomatia laurina (Eupomati.)	L
Euodia micrococca (Rut.)	I +
Exocarpos cupressiformis (Santal.)	S
Ficus coronata (Mor.)	L +
Geranium solanderi (Gerani.)	S +
Glochidion ferdinandi (Euphorbi.)	I +
Glycine clandestina (Fab.)	S +
Guioa semiglauca (Sapind.)	L +
Helichrysum diosmifolium (Aster.)	S
Hibiscus heterophyllus (Malv.)	L +
Hymenosporum flavum (Pittospor.)	L +
Indigofera australis (Fab.)	S +
Legnephora moorei (Menisperm.)	L +
?*Lepidium ruderale* L. (Brassic.)	S
Leucopogon juniperinus (Epacrid.)	S +
Maclura cochinchinensis (Mor.)	L +
Marsdenia rostrata (Asclepiad.)	L +
Melaleuca styphelioides (Myrt.)	S +
Melia azedarach (Meli.)	L +
Mentha diemenica (Lami.)	S
Myoporum debile (Myopor.)	S
Neolitsea dealbata (Laur.)	L
Nicotiana suaveolens (Solan.)	S
Notelaea longifolia (Ole.)	S
Nyssanthes erecta (Amaranth.)	S
Pandorea pandorana (Bignoni.)	I +
?*Passiflora herbertiana* (Passiflor.)	L +
Phyllanthus gasstroemii (Euphorbi.)	I
Plantago debilis (Plantagin.)	S
Plectranthus parviflorus (Lami.)	S +
Pratia purpurascens (Lobeli.)	S
Pseuderanthemum variabile (Acanth.)	S +
Rapanea variabilis (Myrsin.)	I +
Rhodamnia rubescens (Myrt.)	L +
Rubus hillii (Ros.)	L
Rubus parvifolius (Ros.)	S +
Rumex brownii (Polygon.)	S

Leptochloa decipiens (Po.)	S
Libertia paniculata (Irid.)	L
Lomandra longifolia (Lomandr.)	S
Microlaena stipoides (Po.)	S
Oplismenus imbecillus (Po.)	S
Panicum pygmaeum (Po.)	S
Smilax australis (Smilac.)	S +
?*Stipa rudis* (Po.)	S

FERNS

Adiantum formosum (Adiant.)	L
Adiantum silvaticum (Adiant.)	L
Doodia aspera (Blechn.)	L
Pellaea falcata (Adiant.)	L

Additional species recorded by May in 1984

Acacia parramattensis (Fab.)
Celastrus australis (Celastr.)
Croton insularis (Euphorbi.)
Cupaniopsis anacardioides (Sapind.)
Ficus rubiginosa (Mor.)
Maytenus silvestris (Celastr.)
Morinda jasminoides (Rubi.)
Parsonsia straminea (Apocyn.)
Pittosporum revolutum (Pittospor.)
Polyscias sambucifolia (Arali.)
Stellaria flaccida (Caryophyll.)
Stephania japonica (Menisperm.)
Streblus brunonianus (Mor.)

Map unit 10d - Grey Box - Ironbark Woodland

Woodland: *Eucalyptus moluccana - Eucalyptus tereticornis - Eucalyptus crebra*

This community is similar to the previous woodland (Community 10c) but is found on more hilly Wianamatta Shale country with *Eucalyptus crebra* as a co-dominant species. It is part of the Cumberland Plain Woodland of Benson & Howell (1990*a* & *b*). The community was originally extensive around the edge of the Cumberland Plain, being abundant towards Camden and Picton, Kurrajong to Glossodia and Cattai to Prospect.

The understorey is generally grassy with patches of shrubs. Grass species include *Themeda australis, Eragrostis leptostachya* and *Aristida ramosa* and *A. vagans. Bursaria spinosa* is the most common shrub species, often forming dense thickets. Other, less common, shrub species include *Acacia implexa, A. parramattensis* and *Indigofera australis.* A small stand of this community is included in the Longneck Lagoon Field Studies Centre at Pitt Town.

Isolated stands of rainforest scrub vegetation have been recorded from Box Hill at Grose Vale (Carne 1910) (Table 8) and at the 'Native Vineyard' at Cobbitty (Woolls 1867). William Woolls writes: 'This spot [it is about 1 km south-west of Cobbitty Trig] is also remarkable for the occurrence of many plants which do not grow anywhere in the adjacent bush ... The 'Vineyard' as it is called [presumably named because of the predominance of vines and lianes] contains only a few acres, and is almost in sight of the Reverend T. Hassell's residence at Denbigh. It has the appearance of a cultivated shrubbery, rather than that of a collection of plants formed by natural causes'. Many of the native species are now extinct or still surviving as only one or two old plants, largely due to the invasion of *Olea europea* subsp. *africana* which forms dense scrub cover to 10 m high and chokes out the native species. Grazing by domestic stock and rabbits has also prevented seedling growth of many of the native species. Table 9 lists the plant species recorded by Woolls in 1867 and shows those still present in 1976, when the area was visited by the author. Such a group of species, most of which are normally restricted to rainforest, is unusual. A number are particularly rare; *Cynanchum elegans* (Asclepiadaceae), apart from the record by Woolls (it was not recorded in 1976) is known only from a few rainforest remnants near Wollongong

Table 9. Species recorded from the 'Native Vineyard' at Cobbitty by William Woolls (1867). (a, indicates also recorded by D.H. Benson in 1976 and b, recorded by Marie Kennedy in 1991).

Small trees		
Citriobatus multiflorus	a	
Geijera latifolia	a	b
Alectryon subcinereus	a	
Guioa semiglauca		
Alphitonia excelsa		
Diospyros australis		
Streblus brunonianus	a	b
Maclura cochinchinensis	a	b
Croton verreauxii		
Claoxylon australe		
Coelebogyne ilicifolia		
Euodia micrococca	b	

Vines		
Aphanopetalum resinosum	a	
Pandorea pandorana	a	b
Cissus antarctica	a	b
Eustrephus latifolius	a	
Geitonoplesium cymosum	a	
Sicyos australis	b	
Clematis aristata		
Passiflora herbertiana		
Stephania japonica		
Sarcopetalum harveyanum	b	
Cynanchum elegans		
Marsdenia flavescens	a	b
Parsonsia straminea		
Leichhardtia leptophylla		
Convolvulaceae (2 species)		

and scree slopes of Mount Dangar in the Hunter Valley. Similarly the nearest localities to the Native Vineyard for *Geijera latifolia* (Rutaceae) are Albion Park to the south and Pokolbin to the North. Similar vegetation is associated with the more rugged escarpments of Razorback Range between Camden and Picton on outcrops of the sandstone strata of the Bringelly Shale, particularly the Razorback and Mount Hercules Sandstone Members along gullies and cliff lines on sheltered northeast to southeast aspects. Phillips (1947) described a *Brachychiton-Bursaria* shrub stratum group found on outcrops of ostracod sandstone (possibly the Potts Hill Sandstone Member of the Minchinbury Sandstone). At the time these areas were mostly cleared and cultivated with only isolated specimens of *Brachychiton populneus*. Since then most of these have disappeared but it is probable that their original vegetation included 'rainforest type' shrubs.

Very little is known about the local ecological relationships between the three species *Eucalyptus moluccana*, *E. tereticornis* and *E. crebra*. *Eucalyptus tereticornis* may be found on more poorly drained sites than the others, though it also occurs on well-drained hill tops. *E. crebra* is found on dry hilly country, but often interspersed with the other species. It is probably slower growing than the other species. Locally pure populations of any of the species may be found, often in close proximity, suggesting different recruitment requirements may be involved. Past management practices such as the selective cutting of *E. crebra* for fence posts etc. may have led to local loss of this species.

Map unit 14a - Castlereagh Scribbly Gum Woodland

Low woodland: *Eucalyptus sclerophylla - Angophora bakeri*

This unit and the following map units 14b and 14c are part of the Castlereagh Woodlands of Benson & Howell (1990*a*), the characteristic vegetation of the Tertiary alluvial deposits of western Sydney with a very rich but poorly conserved flora.

Low woodland is found on sandy soils of the Tertiary alluvium around Castlereagh-Londonderry and at Holsworthy. It ranges from low woodland to woodland structure, with estimated canopy height ranging from 8 to 12 m. Projected foliage cover ranges from 20–32%. This structure probably approaches the original pre-settlement structure as neither of the main tree species has been cut to any great extent. This is also indicated by the mean basal area for the community (15.4 m^2/ha) (Table 10), which is much higher than the *E. fibrosa* open-forest 11.5 m^2/ha), a community that has been heavily logged. Fire, however, appears to have been frequent in recent times and may have increased the proportion of multi-stemmed plants. The understorey is variable, a 2 m high shrub layer being present at some sites but being replaced by sedges or grassed under conditions of poor drainage or frequent burning.

Eucalyptus sclerophylla, Scribbly Gum, is the most distinctive tree species, occurring as large spreading trees 8 to 12 m high. The most common species, however, is *Angophora bakeri*, generally a small tree with characteristically twisted branches. This species makes up to 70% of the basal area and 82% of stem density compared with 13% basal area and 6% stem density for *E. sclerophylla* (Table 10). Other tree species which may be present are *E. fibrosa*, *E. gummifera*, *E. eugenioides*, and in places with poorer drainage *E. parramattensis* subsp. *parramattensis*, *E. sideroxylon* and *Melaleuca decora*. A small group of *E. eximia* trees were found at the southern end of Castlereagh State Forest and may be a chance colonisation from the lower Blue Mountains. *Angophora bakeri* seems to be very tolerant of a wide range of drainage conditions and is equally common with *E. sclerophylla* on well drained sites, and *E. parramattensis* on poorly-drained ones.

Table 10. Basal area and density of major tree species from 6 sites in Castlereagh Scribbly Gum Woodland.

	Basal area (m²/ha)			Density (plants/ha)		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Angophora bakeri	10.84	2.0	70	496	139	82
Eucalyptus sclerophylla	2.06	1.4	13	38	17	6
Total	15.42	1.7		604	132	

Other species contributing to total basal area are *Eucalyptus fibrosa*, *E. gummifera*, *E. parramattensis* subsp. *parramattensis* and *Melaleuca decora*.

The understorey is of sclerophyllous shrubs. These may form a continuous cover or be more open, with grasses in between. Common shrub species are *Banksia spinulosa* var *spinulosa*, *Grevillea mucronulata*, *Hakea sericea*, *Leptospermum trinervium* and *Melaleuca nodosa*. At least two nationally rare shrub species endemic to the Tertiary alluvium of western Sydney, *Micromyrtus minutiflora* and *Persoonia nutans*, are found in this community. Recently a new species of *Allocasuarina*, *Allocasuarina glareicola* was discovered and described in Castlereagh State Forest in this community. There are only two small populations so far known.

The more open communities often result from frequent burning which favours the grasses and sedges at the expense of the shrub species. Common species are *Themeda australis*, *Eragrostis brownii*, *Patersonia sericea* and *Cyathochaeta diandra*. At certain times in the year ground orchids may be conspicuous.

This community usually grades gently into the adjacent *E. fibrosa* open-forest or *E. parramattensis* subsp. *parramattensis* low woodland. Where it adjoins communities on Wianamatta Shale the transition may be much more abrupt.

Soils on sites occupied by Scribbly Gum Woodland are very poor and until recently this community remained essentially undisturbed. However, extensive extraction of sand and gravel is now resulting in the removal of much vegetation, whilst the subdivision of much of the remainder into small holdings for suburban development, hobby farms, poultry farms etc. is also decreasing its extent. No examples have been reserved by the National Parks and Wildlife Service though proposals to make Castlereagh State Forest a Nature Reserve or Flora Reserve would ensure good conservation of this community. In general the future for the community appears to be poor. Hobby farm development results in the removal of understorey species and their replacement with exotic grasses, whilst council reserves are generally mown with similar results. The latter is regrettable for with care such remnants could be preserved in many areas as local examples of the original vegetation.

As far as disturbance, viability and management are concerned, similar comments to the Castlereagh Ironbark Forest, apply to this community. It is a well-drained community, on a nutrient poor soil which acts as a buffer to exotic weed invasion. Only three exotic species were recorded in this survey. The apparent uselessness of this soil type for agriculture and the unspectacular nature of the flat terrain make it appear as 'useless scrub', but if efforts are made to retain small stands in reserves etc., the richness and nature of the species in them could be successfully conserved.

Map Unit 14b - Agnes Banks Woodland

Low woodland/open-scrub: *Eucalyptus sclerophylla - Angophora bakeri - Banksia serrata.*

At Agnes Banks, south-west of Richmond, is a deposit of windblown sand of Pliocene-Pleistocene Age (Gobert, 1978) that supports an interesting shrub-dominated community, floristically similar to that found on coastal sand dunes such as those near Myall Lakes.

Soil depth varies from very thin at the edges, where the sands overlie the clay soils of the underlying Tertiary alluvium, to up to 7 m thick at the dune crests. On crests and ridges a 'coffee-rock' pan (<5 cm thick) occurs about 80 cm below the surface. On footslopes and in swales this pan is missing or may be discontinuous (Bannerman & Hazelton 1990). This pan may direct water into the swales increasing the differences in moisture between crests and swales. The relationship of vegetation to drainage conditions and the effects of a perched water table above a 'coffee-rock' horizon are shown in Figure 5.

Community structure is predominantly woodland to low woodland, but ranges from low open-forest to sedgeland. The characteristic tree species on well-drained sites are E. *sclerophylla* and *Angophora bakeri* and on poorly-drained sites *E. parramattensis*. *Banksia serrata* is generally a smaller but very distinctive tree species. Benson (1981) describes the vegetation in terms of five plant communities which occur in a sequence along a drainage gradient. These are:

a) **Low open-forest of *Banksia serrata* and *Angophora bakeri*.** A community apparently originally confined to the well-drained crests of the large dunes, most of which have been completely removed by sand extraction. The main trees are *Banksia serrata* and *Angophora bakeri*, up to 10 m high but the community may have occasional large, emergent trees of *Eucalyptus sclerophylla* up to 13 m. There is an open understorey of *Pteridium esculentum* and *Imperata cylindria* and scattered shrubs including *Ricinocarpos pinifolius, Eriostemon myoporoides* and *Bossiaea rhombifolia*.

b) **Woodland of *Eucalyptus sclerophylla, Angophora bakeri* and *Banksia serrata*.** This is the most widespread community, found on well-drained sites. It is dominated by trees of *Eucalyptus sclerophylla* 10 to 15 m high, together with smaller trees of *Angophora bakeri* and *Banksia serrata*. A large number of sclerophyllous shrub species is characteristic of the understorey, common species being *Leptospermum trinervium, Conospermum taxifolium, Ricinocarpos pinifolius* and *Isopogon anemonifolius*.

c) **Woodland of *Eucalyptus sclerophylla, E. parramattensis* subsp. *parramattensis* and *Banksia aemula* [previously *B. serratifolia*].** At the southern end of the sand deposit is woodland dominated by *Eucalyptus sclerophylla* but which appears to be restricted to shallower or less well-drained sand than Unit (b). Small trees of *E. parramattensis* up to 10 m high and large shrubs of *Banksia aemula* up to 7 m high are generally present. An understorey of sclerophyllous shrubs, similar to that in (b) above, is usually present. *Banksia aemula* may indicate more podsolised soils than Unit (b) with *B. serrata*, a situation reported for Myall Lakes (Myerscough & Carolin 1986).

d) **Low open-woodland of *Eucalyptus paramattensis* subsp. *parramattensis*.** This community is confined to poorly-drained situations. Small trees of *E. parramattensis* less than 10m high, either in clumps or as scattered individuals, are dominant though *E. sclerophylla* and *Angophora bakeri* may be present occasionally. The understorey is dominated by *Banksia oblongifolia*, which is in the most low-lying sites form a low shrubland, devoid of trees. Large tussocks of sedges and rushes are common. One sedge species, *Restio pallens*, common on the north coast of NSW and in southern Queensland reaches its southern limit at Agnes Banks.

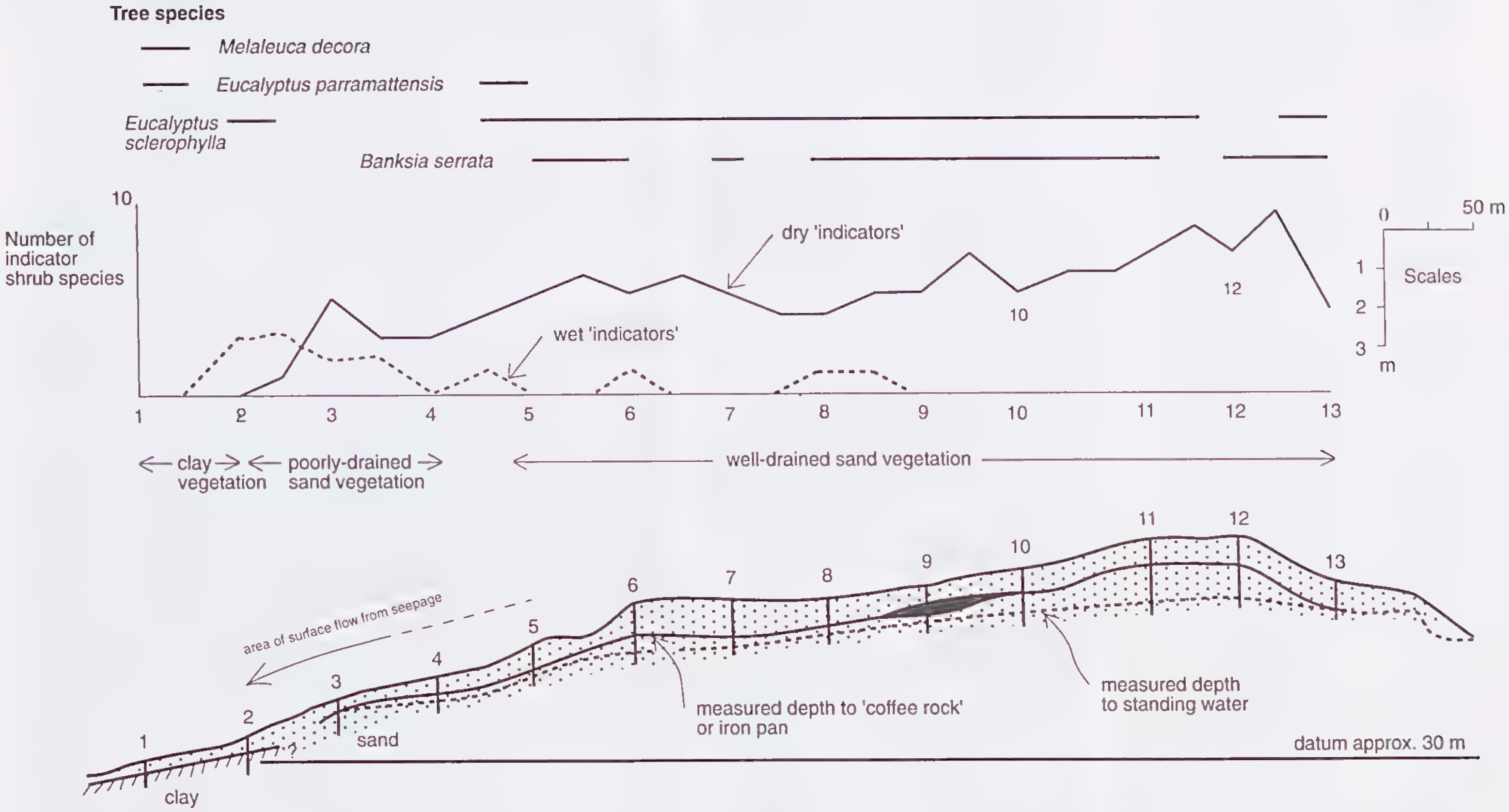


Figure 5. Occurrence of characteristic species along transect across sand dune at Agnes Banks showing relationship between topography and depth of iron pan. 'Wet' and 'dry' indicator species are those known from previous experience to be confined to particular moisture conditions.

e) **Sedgeland of *Lepidosperma longitudinale*,** with the small shrub *Melaleuca thymifolia*, occurs in a limited area in depressions between the main dunes where drainage is severely impeded. This vegetation has now been completely destroyed by mining and *Lepidosperma longitudinale* no longer occurs in western Sydney.

The vegetation on the sand deposit contrasts markedly with the surrounding vegetation and the boundary between the sand and the clay soils of the Tertiary alluvial deposits is very distinct. On the clay the dominant tree species becomes *Eucalyptus fibrosa* and the rich shrub understorey is replaced by a more open one predominantly of *Melaleuca decora* and *Bursaria spinosa* with a dense ground cover of grasses.

Part of this community is conserved by the Agnes Banks Nature Reserve but the area represented, 16 ha, is inadequate. Because it is on the shallowest sand, it preserves only a limited number of the characteristic species of the sand, and does not include examples of the low open-forest of *Banksia serrata - Angophora bakeri*, or the sedgeland of *Lepidosperma longitudinale*, or very much of the woodland of *E. sclerophylla - Angophora bakeri - Banksia serrata*. A Commission of Inquiry (Cleland 1988) found a further adjoining area to the north, to be of significance and a Permanent Conservation Order was recommended and later imposed by the Minister. The remaining sand area is proposed to be mined for construction sand.

Map unit 14c - Swamp Woodland

Low woodland: *Eucalyptus parramattensis* subsp. *parramattensis* - *Melaleuca decora*

Along creeklines, particularly Rickabys Creek, and in poorly-drained depressions on Tertiary alluvium near Castlereagh and Londonderry, is low woodland of *Eucalyptus parramattensis* subsp. *parramattensis* and *Melaleuca decora*. Occasional tree species include *Eucalyptus sideroxylon* and *E. sclerophylla*. Tree height at recorded sites ranged from 8 to 12 m and projected foliage cover from 8 to 18%. Basal area and plant density are much lower than the associated Castlereagh Ironbark and Scribbly Gum woodland (Table 11), but are probably indicative of the original structure, as the community has suffered little disturbance because of the poor agricultural soil and poorly-drained sites where it occurs. The main tree species, *E. parramattensis* subsp. *parramattensis* makes up about 31% of basal area and 44% of plant density (Table 11). Stem diameters are generally small and almost always less than 25 cm d.b.h. The associated tree species *Melaleuca decora* and *E. sclerophylla* may both have larger stem

Table 11. Basal area and density of major tree species from 3 sites in *Eucalyptus parramattensis* subsp. *parramattensis* low woodland.

	Basal area (m²/ha)			**Density (plants/ha)**		
	mean	(± s.e.m.)	% of total area	mean	(± s.e.m.)	% of total density
Eucalyptus parramattensis	1.96	0.8	31	166	74	44
Melaleuca decora	1.76	1.7	28	83	71	22
E. sclerophylla	1.20	0.6	19	75	43	20
Total	6.39	0.7		375	80	

Other species contributing to total basal area are the tree *Eucalyptus sideroxylon* and the small tree *Angophora bakeri*.

diameters, though *E. sclerophylla* is generally a smaller tree than where it is found in Scribbly Gum Woodland.

The understorey is grassy and herbaceous with many annual or ephemeral species which respond to wet conditions. Density varies with the frequency and period since the last fire. The shrub layer may be mid-dense to open. Common species are *Banksia oblongifolia, Kunzea capitata, Hakea sericea* and *Melaleuca thymifolia.* The ground cover may be grassy and herbaceous or up to 60% bare. Common ground species are *Themeda australis, Imperata cylindrica, Dianella revoluta* and *Lepyrodia* species. Many species are annual or perennial and respond to wet conditions. These include *Isotoma fluviatilis* subsp. *fluviatilis, Gratiola pedunculata, Elatine gratioloides, Nymphoides geminata, Haloragis heterophylla, Lythrum hyssopifolia* and *Boronia polygalifolia.* Other species are particularly conspicuous after fire including *Ptilanthelium deustum* and terrestrial orchids including *Caladenia caerulea, C. carnea, Diuris maculata* and *Lyperanthus suaveolens.*

Depending on drainage Swamp Woodland may grade either gradually or abruptly into the associated Scribbly Gum Woodland (community 14a).

Many of the swamp woodland species have narrow habitat requirements and although widespread in distribution, are now rare or vulnerable because of loss of habitat, particularly on the Cumberland Plain, where most creeks and wet areas have been severely disturbed. For many of these species at least over half of herbarium collection sites on the Central Coast botanical subdivision are now likely to have been destroyed. One species *Hypsela sessiliflora*, originally collected from wet sites on the western Cumberland Plain has now been declared extinct (Briggs & Leigh 1988).

Swamp Woodland is potentially viable in the long-term. Because of the low nutrient status and poor agricultural value, it has remained essentially undisturbed, the low nutrient status and somewhat sandy nature of the soil being a buffer to exotic weed invasion except perhaps for *Andropogon virginicus.* Its poor drainage and occurrence in depressions and drainage channels, however, makes it susceptible to nutrient inflow and sedimentation, both of which facilitate weed invasion. Furthermore, it is now threatened by extensive clay-shale extraction proposals and hobby farm and suburban subdivision. No examples of this community have been reserved by the National Parks and Wildlife Service though a proposal to enlarge Agnes Banks Nature Reserve to the south, thereby including a good example of this community is now being considered. Castlereagh State Forest also includes some areas of this community.

Map unit 21f - Lower Blue Mountains Heath

Open-heath: *Eucalyptus stricta - Allocasuarina nana*

Open-scrub: *Angophora hispida*

Open-heath and open-scrub form part of the Sydney Sandstone Complex (in particular part of the Sydney Sandstone Ridgetop Woodland map unit 10ar). Open-heath is extensive enough to be mapped separately south of Woodford. Here it occurs on a series of rocky ridgetops along the Woodford Range. Characteristic species are the mallees of *Eucalyptus stricta* which here may have intergrading characteristics with *E. apiculata*, also *E. multicaulis, E. consideniana* and *E. oblonga.* A variety of shrub species is common including *Banksia ericifolia, Dillwynia floribunda* and *Petrophile pulchella*, together with ground species including *Lepidosperma flexuosum, Schoenus villosus, Restio fastigiatus, Patersonia glabrata* and *Lepyrodia scariosa. Allocasuarina distyla* is generally more common than *Allocasuarina nana.*

Small patches of open-scrub with *Angophora hispida* are found around Annangrove and Maroota, and in the former Maroota State Forest. Here rock platforms may have heathy 'islands' of shrubs growing in shallow soil in hollows in the rock. A rare shrub species endemic to those sites in the Maroota area is *Kunzea rupestris*. Characteristic species of these sites include *Calytrix tetragona, Dillwynia floribunda, Grevillea buxifolia, Petrophile pulchella* and *Platysace ericoides*. This vegetation probably represents a lower rainfall variant (annual rainfall about 800 mm) of the more coastal sandstone heath (annual rainfall 1 000-1 200 mm) found in Ku-ring-gai Chase and Marra Marra National Parks, rather than being Lower Blue Mountains Heath. Such areas are too small to show on the Penrith Map.

Map unit 26a - Blue Mountains Sedge Swamps

Closed-sedgeland: *Gymnoschoenus sphaerocephalus - Lepidosperma limicola - Xyris ustulata - Baeckea linifolia*

This community, part of the Hawkesbury Sandstone Complex, is restricted to a number of poorly-drained sites on the Hawkesbury Sandstone plateau north of Springwood. These are generally related to impervious shale strata which collect the water and direct it out along springs and soaks which often follow topographic contours. Floristic composition is related to moisture availability and sediment depth. With deep sediment and permanent moisture the characteristic species are *Gymnoschoenus sphaerocephalus, Lepidosperma limicola, Xyris ustulata* and *Baeckea linifolia*. Where moisture is ephemeral, *Lepyrodia scariosa* predominates (Holland, Benson & McRae 1992). The main occurrence of sedge swamp however is in the higher Blue Mountains further west, from Wentworth Falls to Clarence where sedgeland and swamps are a characteristic feature of the landscape (Keith & Benson 1988).

Map unit 28a - Freshwater Wetlands

Open-sedgeland: *Eleocharis sphacelata - Juncus usitatus - Persicaria* spp.

Shrubland: *Melaleuca linariifolia*

Freshwater wetland and swamp communities were once a feature of the Nepean–Hawkesbury floodplain. In the lower Hawkesbury between Pitt Town and Wisemans Ferry, these wetlands or 'backswamps' form in the depression between the levee bank along the River edge and the sandstone hillsides of the main river valley. Below Wisemans Ferry, wetlands are estuarine and influenced by salinity (see map unit 4a). Upstream of Pitt Town wetlands are less frequent and occur as depressions on the river floodplain. Most have now been cleared or drained. Indeed remnant wetlands vary considerably in terms of floristic composition, drainage and flooding conditions and water quality, and it is difficult to generalise on wetland behaviour.

Zonation patterns may be recognised in particular wetlands and related broadly to differences in water depths and periods of inundation. Floodplain wetlands may have areas that are permanently wet, semi-permanent with water present most of the year, or seasonal, which are dry for the greater part of the year depending on local rainfall conditions. Permanent and semi-permanent wetlands may have emergent reedland of *Eleocharis sphacelata*, which may grow to 1–2 m above the water level. *Typha* spp. may indicate higher-nutrient conditions or brackish water. Common smaller species are *Ludwigia peploides* subsp. *montevidensis, Triglochin procera, Myriophyllum* spp. and *Philydrum lanuginosum*. Death of above-ground vegetation during winter may result from severe frosts. Permanent wetlands often have extensive areas of open water sometimes with floating or submerged vegetation, depending on water depth or seasonal conditions.

Seasonal wetland zones do not usually have standing water, except following rain or during flooding, but the soil is often waterlogged or very moist. They may have rushland with tussocks of *Juncus usitatus* or herbland with scrambling *Persicaria* spp. (*P. decipiens, P. hydropiper, P. lapathifolia, P. praetermissa*). Less common are *Myriophyllum, Marsilea* and *Ranunculus* spp. There may be scattered individual shrubs where stock grazing has prevented regrowth or tall shrubland with *Melaleuca linariifolia, M. styphelioides* or *Casuarina glauca*. Depending on the topography the tall shrubland may grade into *Eucalyptus robusta* swamp woodland or, more commonly give way to *E. amplifolia* subsp. *amplifolia* - *Angophora subvelutina* River-flat Forest or Grey Box Woodland. In general the forest or woodland near wetlands has been cleared.

Remaining floodplain wetlands are concentrated in the area between Richmond and Sackville. Adam & Stricker (1989) record 25 floodplain wetlands for the 1:25 000 Wilberforce map sheet area that covers this area. These cover about 860 ha or over 80% of the total area of remaining floodplain wetland for the Penrith map sheet area (Figure 6). Sites with high conservation capability ratings include Wheeny Lagoon, Broadwater/Little Cattai Creek, Portland Head Farm, Reedy Swamp, Hawkesbury Campus of the University of Western Sydney and Castlereagh State Forest.

By their nature, many wetlands are narrow strips too small to show at the 1:100 000 scale of the Penrith map. Their absence does not indicate lack of importance, merely

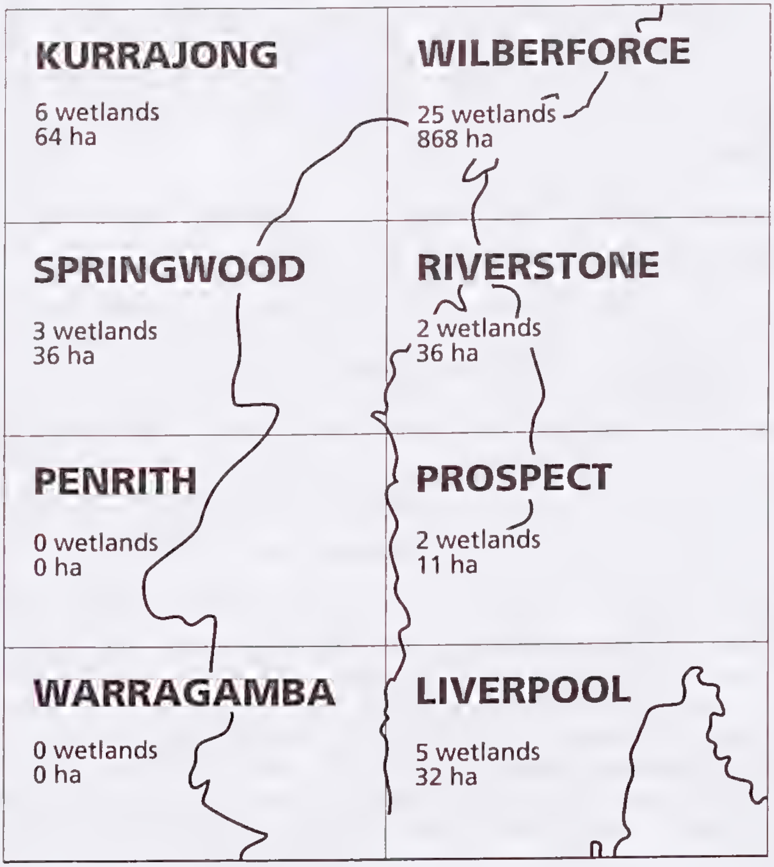


Figure 6. Area (ha) and number of floodplain wetlands within 1:25 000 map areas of the Penrith sheet. Data from Adam & Stricker (1989).

technical limits to their representation. Examples are Reedy Swamp in Mitchell Park, Pughs Lagoon near Richmond, backswamps between Yarramundi and Lowlands and at McGraths Hill.Though much freshwater swamp has been drained and replaced with improved pasture, indications of the original swamp vegetation may remain. *Juncus* spp. particularly *J. usitatus*, are of low palatability to stock and may persist.

Floodplain wetlands on the Georges River include Horseshoe Pond, New Brighton, Deepwater Park, Stockade Reach and Voyager Point. Voyager Point has an extensive wetland in very good condition. It is cut off from the Georges River by a levee bank and consequently fresh, rather than estuarine. In its upper parts the vegetation is low woodland and scrub with shrubs of *Melaleuca nodosa* and small trees of *Eucalyptus parramattensis* subsp. *parramattensis*. This is on very low nutrient soils derived from Tertiary alluvium. Further down tall shrubs of *Melaleuca ericifolia* and *M. decora* predominate, while at the northern end is an extensive area of sedgeland, with *Eleocharis sphacelata*, *Triglochin procera* and *Typha orientalis*. At the time of inspection there were extensive areas of open-water with a variety of small floating water plants such as *Myriophyllum*, *Utricularia* and *Nymphoides*. There is considerable fluctuation in the water level over the seasons. For example in August 1986 there was very little water. The vegetation here is extremely good condition with healthy native vegetation and very few weeds.

Wetlands in the Lower Blue Mountains are not floodplain wetlands but generally associated with deep sandy soils, very low nutrient status and impeded drainage. Burralow Swamp at Kurrajong on the margin of Blue Mountains National Park is an isolated wetland draining south to the Grose River. It is part of Burralow Swamp Soil Landscape (Bannerman & Hazelton 1990) and has a more sandy substrate than the floodplain wetlands, a very low fertility status (compared with the moderate fertility of the floodplain wetlands), very little standing water and a predominance of shrubs and ferns. Species include *Leptospermum polygalifolium*, *Hakea salicifolia*, *Hypolepis muelleri*, *Gleichenia dicarpa*, *Eleocharis sphacelata* and *Gahnia clarkei*. Other creeks in the Lower Blue Mountains, with deep sandy alluvium, such as Long Angle, Frasers and Fitzgeralds Creeks have similar vegetation often with *Melaleuca linariifolia* and forest of *Eucalyptus deanei*. Glenbrook Lagoon is a permanent open-water wetland of similarly low nutrient status with important sedgeland of *Lepironia articulata*, one of very few occurrences of this species in the Sydney area.

Seasonal wetlands have probably suffered the most from disturbance from draining, damming or grazing. Species in these sites probably depend on fluctuating water levels to promote growth and flowering. Alterations such as draining or damming stop seasonal levels from fluctuating and reduce sites for seasonal wetland species. Many of these are becoming rarer, but because we have limited data on their distributions, changes are difficult to quantify. At Longneck Lagoon, long term higher water levels and possible changes in water quality have occurred with a loss of wetland species and the growth of previously less common species.

Though there have been several general surveys of the extent of swamps along the Nepean–Hawkesbury system (Royal Botanic Gardens, 1986; Adam & Stricker 1989), there has been very little work on the plant ecology of the swamps themselves, despite the changes that are evident in lagoons like Longneck where past disturbance from stock grazing, draining and, most recently, partial damming by roadworks has altered the relative extent of vegetation zones and introduced a large number of exotic species. The task of separating the changes resulting from human activities - catchment disturbance and hydrological alterations - from climatically induced change, is difficult. However more information on these aspects is needed if adequate management of surviving wetlands is to be undertaken (Figure 7).

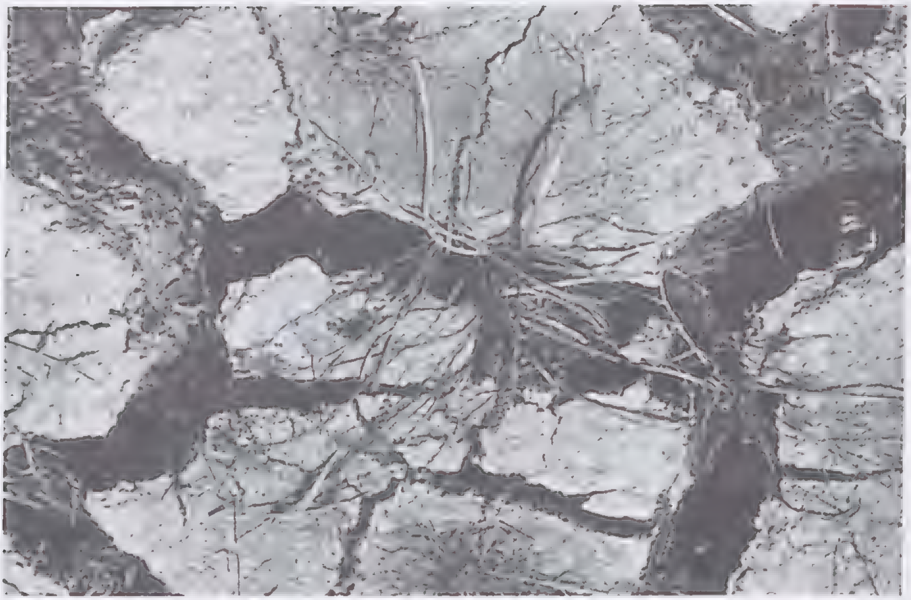


Figure 7. Floodplain wetland plants are adapted to fluctuating water levels; short periods of dryness can promote germination and establishment of new plants, such as *Triglochin procera* shown in mud cracks here at Reedy Swamp, Cattai, following a dry spring.

Cleared areas

Agricultural development and urban settlement have generally followed the more fertile soils of the alluvial flats and the Wianamatta Shale of the Cumberland Plain. The low nutrient soils of the Hawkesbury Sandstone and Tertiary alluvium have frequently survived with natural vegetation though extensive areas of Tertiary alluvium are now being cleared for extraction of sand and gravel. The major wildlife reserves are all on Hawkesbury Sandstone.

Discussion

Vegetation patterns

Vegetation patterns shown on the map sheet are limited by the scale of the final work. At 1:100 000 scale areas less than about 200 m across, for example, cannot be reproduced. Mapping conventions use lines to indicate boundaries, which may in reality be ecotones or gradations. Plant communities themselves may vary in composition in a much more complex way than can be indicated by assigning dominant species which may or may not be present at any particular place. The mapping units recognised here are subjective and result from observation and correlation of landform and floristic features. These correlations have not been experimentally confirmed though many of the patterns recognised have been proposed by earlier writers and confirmed by the extensive field observations of the present writer.

The close relationship between vegetation and geology in the Sydney area was recognised by the early explorers and settlers and used to assess potential land use (see earlier quotations). Many of their observations were confirmed later by scientists; Barwick (1903) and Carne (1908) describe the characteristic flora associated with volcanic necks. Cambage (1905) describes species restricted to areas of Narrabeen Group geology, and differences between the vegetation of the Wianamatta Shale and Hawkesbury Sandstone. Pidgeon (1937, 1941) described the major vegetation types confined to these geologies and Phillips (1947) discussed the differences between the vegetation on Wianamatta Shale, Tertiary alluvium and Holocene alluvium, respectively. Pidgeon described vegetation in terms of climax communities with the Precipitation/Evaporation index as a measure of the principal factor determining the distribution of vegetation. She stated that on shale the climate factor, and on sandstone the soil factor, is limiting. Phillips pointed out, however, that the soil and climate are interacting factors. Beadle (1962) demonstrated that nutrients, particularly soil phosphate are important in the distribution of vegetation types, and that the introduction of nutrients in the normally low nutrient soils both inhibits growth of native species and promotes the invasion of exotic weed species. Current thinking rejects the earlier concepts of climax communities (e.g. Clements 1936) and interprets vegetation patterns in terms of responses of species to variations in geology, soil texture and fertility, soil moisture relations and local climate.

That soil fertility alone is not a sufficient indicator of vegetation is shown in Table 12. Here soil fertility groups (in terms of chemical composition) as determined for the soil landscapes of Bannerman & Hazelton (1990) are related to vegetation. The findings follow the general trends with vegetation on volcanic soils being most mesic and the scleromorphic heaths being found on very low-nutrient soils. The Floodplain

Table 12. Soil fertility (from Bannerman & Hazelton 1990) for various plant communities.

Soil fertility	Plant community	Map code
Moderate:	Glen Forest	6c
	Freshwater Reed Swamps-floodplain wetlands only	28a
Moderate-low:	Spotted Gum Forest	9b
	Turpentine - Ironbark Forest	9o
	Grey Box Woodland	10c
	Grey Box - Ironbark Woodland	10d
Low:	Shale Cap Forest	9a
	Ironbark Forest	9c
	Shale/gravel Transition Forest	9d
	Castlereagh Ironbark Forest	9e
	River-flat Forest	9f
	Sydney Sandstone Gully Forest	10ag
	Castlereagh Scribbly Gum Woodland	14a
	Swamp Woodland	14c
Low-very low:	Camden White Gum Forest	6d
	Agnes Banks Woodland	14b
Very low:	Estuarine Complex	4a
	Sydney Sandstone Ridgetop Woodland	10ar
	Lower Blue Mountains Heath	21f
	Blue Mountains Sedge Swamps	26a
	Freshwater Reed Swamps-Lower Blue Mtns wetlands	28a

Forests, however, presumably with some of the biggest trees, and certainly the areas sought for cultivation by the early settlers, occurred on low nutrient soils according to Bannerman & Hazelton (1990). It would appear that soil texture, a permanent water supply and periodic flooding probably compensated for the low soil nutrients, which are indeed lower than for the nearby shale soils.

Regional affinities

The Penrith Map Sheet Area includes the largest areas of the Wianamatta Shale and Tertiary alluvial soils in the Sydney area. The Cumberland Plain Woodlands (Map Units 9b, 10c, 10d) are part of the Box Woodlands of the East and South-East described by Beadle (1981), in particular, part of his *Eucalyptus moluccana* Alliance. This occurs in rainshadows near the coast, e.g. the Cumberland Plain and the floors of the Hunter and Clarence River valleys, as well as patchily in the intervening areas, with outliers in the south, the drier parts of the Illawarra Plain, the Araluen and Bega valleys and a northern extension in small isolated stands as far as the Tropic of Capricorn. Beadle gives a number of grass and herb species for the Cumberland Plain and Hunter Valley though it is apparent that associated species are quite different as the Tropic is approached.

The Castlereagh Woodland is part of Beadle's Ironbark Forests and Woodlands of the East, and is referred to under his *Eucalyptus crebra* Suballiance, though the communities at Castlereagh contain more *Eucalyptus fibrosa* and even *E. sideroxylon* than *E. crebra*. The *E. crebra* Suballiance occurs throughout a large area of Queensland from north of the Tropic, through south-eastern Queensland onto the coastal lowlands of N.S.W. The communities form ecotonal associations with the low fertility coastal assemblages (i.e. the sandstone flora), according to Beadle.

Differences between shale, sandstone and alluvial floras have been recognised for many years, both in the observations of early settlers as they searched for indicators of better agricultural land, and in the work of Pidgeon, Phillips, Beadle etc. The distinctiveness of the flora on Tertiary alluvium was recognised by Phillips but only became more generally known in the 1970s. The need for representative areas of communities of soils other than sandstone is discussed in Benson & Howell (1990*a* & *b*).

Regional resemblances of the floras on the different soil types are interesting. During a study of the rare plants of Western Sydney, total floristic lists for the Cumberland Plains Woodland (439 species) and the Castlereagh Woodland (242 species) were compiled. Using distributional data from an updated version of Jacobs & Pickard (1981) we compared these floras with the total floras for the Botanical divisions and subdivisions of New South Wales (Table 13). We also compared the sandstone flora of Ku-ring-gai Chase National Park (313 species). The results show that whilst the flora of the Cumberland Plain Woodlands and the Castlereagh Woodlands has strongest resemblances with the Coastal subdivisions, nearly 75% of the Cumberland Plain flora also occur on the Western Slopes and nearly 45% on the Western Plains. The figures for the Castlereagh Woodlands are slightly lower at 66% and 37% respectively. This is much higher than for the Hawkesbury Sandstone flora, where only 34% of species occur on the Western Slopes and 10% on the Western Plains. It is also worth noting that, as well as having a similar floristic composition to the flora of the Cumberland Plain, that of the Western Slopes has been subjected to similar clearing and grazing pressures and is also poorly conserved (Figure 8).

In examining the current distribution of the vegetation it should also be borne in mind that species distributions have varied in response to fluctuating past climatic change. About 20 000 years ago, during the coldest part of the last of the Pleistocene

Table 13. Comparison of western Sydney flora with other botanical subdivisions of New South Wales.

Vegetation type*	No. of species	Percentage of species also occurring in				
		NC,SC	NT,CT,ST	WS	WP	FWP
Cumberland Plain Woodlands	439	94	87	74	44	17
Castlereagh Woodlands	242	92	87	66	37	10
River-Flat Forests	216	95	92	70	39	12
Hawkesbury Sandstone (Ku-ring-gai Chase NP)	313	85	81	34	10	2

*from Benson & Howell (1990a)
NC-North Coast, **SC**-South Coast
NT-Northern Tablelands, **CT**-Central Tablelands, **ST**-Southern Tablelands
WS-Western Slopes
WP-Western Plains
FWP-Far Western Plains

ice ages, the sea fell to its lowest level, 120–140 m below the present level (Benson & Howell 1990*a*). Given the close correlations of many species with climate today it is not unreasonable to speculate on vegetation patterns at this time. Many of the species on the Cumberland Plain are also found in the Tablelands and Slopes and are likely to have been able to cope with the colder and drier conditions. The Floodplain forests are likely to have migrated further down the Hawkesbury into the sheltered protection offered by the unflooded valleys of Broken Bay and Port Jackson. The coastal plain, beyond todays coastline, may have had sand dunes and alluvial soils perhaps with *Eucalyptus pilularis - Angophora costata* forests and associated vegetation similar to that found on the coastal lands at Myall Lakes. As sea level rose again to reach its present level about 6,000 years ago, it drowned the coastal river valleys of the Hawkesbury and formed the present floodplain. Coastal species including *Banksia aemula* and *Restio pallens*, another 'wallum' species, could have been dispersed inland to colonise suitable sandy substrates such as at Agnes Banks. A number of other Cumberland Plain species have disjunct coastal occurrences today - *Pimelea spicata, Thesium australe, Melaleuca nodosa* - possibly remnants of past migration patterns.

Such comments are speculative - more research into pollen studies, variation patterns within species and ecology and physiology is needed. However if we are to retain the raw material for these studies, conservation of adequate in situ populations across the area, not contaminated by genetic material transplanted from other areas, is necessary.

Rare or endangered species

A list of the native flora of western Sydney - covering most of the Penrith Sheet - has been recently prepared (Benson & McDougall 1991). This lists nearly 1 000 native species for the area with their conservation status. Many of these species are now very rare; 373 are regarded as vulnerable in a regional context. Of a list of 84 species, regarded as having particular conservation significance in western Sydney, 44% were

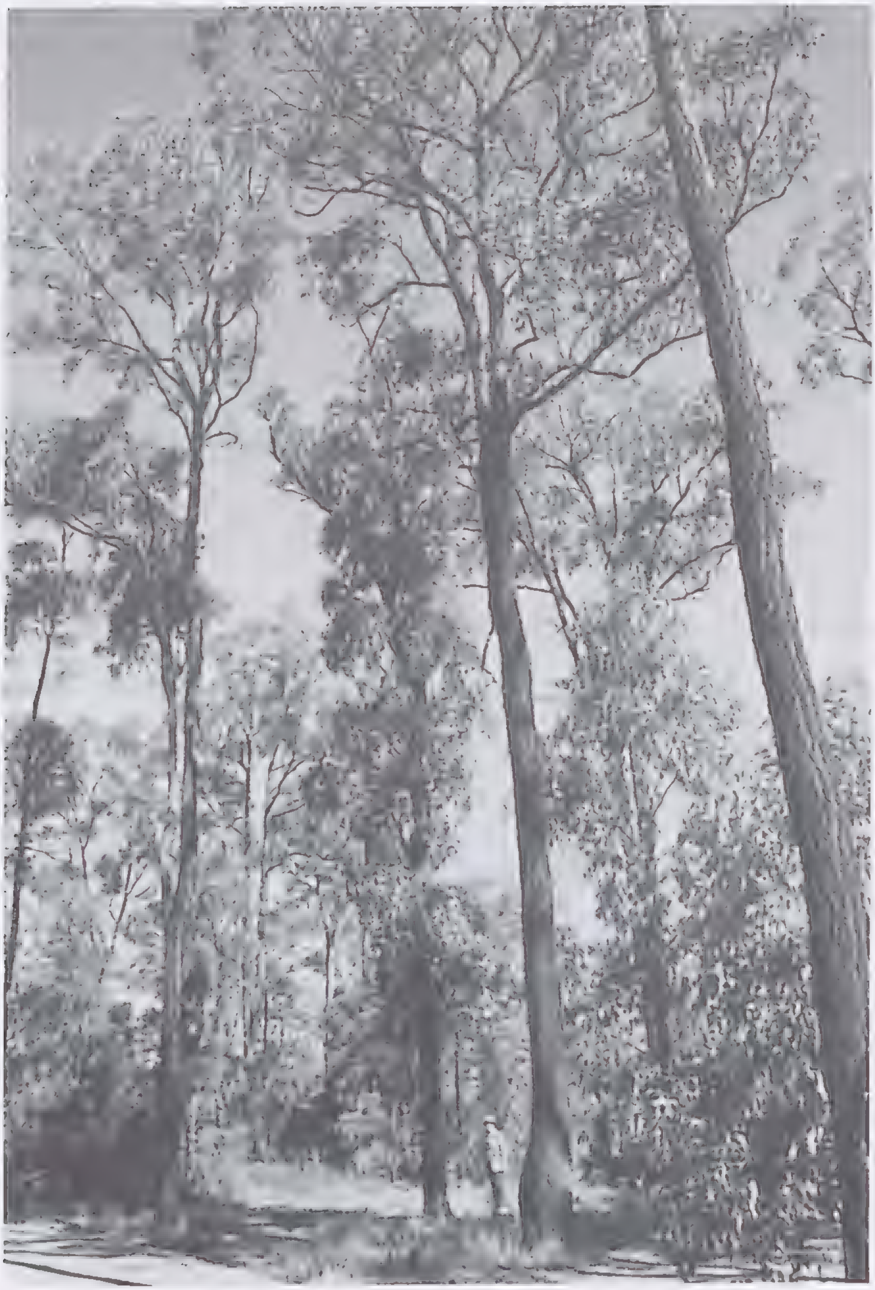


Figure 8. Some of the species found in the Castlereagh Woodland, such as the ironbarks *Eucalyptus fibrosa* and *Eucalyptus sideroxylon* also occur on the Western Slopes of New South Wales, under similar rainfall and soil conditions. Genetic differences between coast and inland populations provide potential scientific research material.

recorded in the Cumberland Plain Woodlands and 36% in the River-flat Forests (including freshwater wetlands), highlighting the need for better conservation of remnants of these vegetation types. Species of particular conservation significance within the Lower Blue Mountains region (not covered by Benson & McDougall) are given in Table 14.

At the very least, conservation plans for all those on the national list (Briggs & Leigh 1988) such as *Pultenaea parviflora, Micromyrtus minutiflora, Persoonia nutans, Acacia pubescens* (the largest remaining population, at Prestons, is currently threatened) and *Pimelea spicata* should be carried out urgently.

Conservation of vegetation

Long-term conservation strategies to conserve and enhance natural vegetation in the Penrith sheet area are needed. These should include:

1. Protection of major reserves and their catchments

Table 15 and Figure 9 show the conservation reserves for plant communities on the Penrith Sheet. Though large areas of sandstone country on the Lower Blue Mountains are protected, it is clear that conservation of the western Sydney vegetation, and in particular the Cumberland Plain and Castlereagh Woodlands is inadequate. Conservation of these areas has been actively sought since the early 1970s, but increasing land prices and the tendency to put off difficult land use decisions, has impeded progress. Recommended major conservation areas given in Benson & Howell (1990*a*) are:

- The catchment of Longneck Lagoon which includes important areas of Grey Box woodland and protects the catchment of this important wetland;
- The southern additions to Agnes Banks Nature Reserve; these would protect significant areas of Castlereagh Woodland on poorly drained sites;
- Castlereagh State Forest, which needs permanent protection as a flora reserve for its important ironbark forests and diverse flora;
- Commonwealth land at Shanes Park, which should be acquired to protect intergrading vegetation on shale and Tertiary alluvium;
- The Mulgoa Nature Reserve proposal with its interesting shale cliff-line habitat;
- The Kemps Creek Nature Reserve proposal, which should be established to protect low-lying Cumberland Plain Woodland;
- Water Board land around Prospect Reservoir, needing permanent protection for its important woodlands.

To date (February 1992) none of these areas have been formally protected.

2. Identification and protection of small remnants

Much of the long-term conservation of the flora of western Sydney will depend on the conservation and management of small reserves by a number of different authorities including the N.S.W. National Parks and Wildlife Service, Forestry Commission, Water Board, and about 10 local councils. Success will be patchy and depend in the long term on availability and application of specific information on the nature of the particular reserve, together with a general increase in education in environmental management.

Table 14. Species of particular conservation importance within the Lower Blue Mountains region of the Penrith 1:100 000 map sheet. For significant species of the western Sydney and Cumberland Plain region, see Benson & McDougall (1991).

Species listed here are either rare or threatened (from Briggs & Leigh 1988) or of significance in terms of geographic distribution, or localised populations disjunct from other occurrences.

DICOTYLEDONS

CHLOANTHACEAE
Chloanthes glandulosa- Springwood to Kurrajong, main population, (one record for South Coast)

CUNONIACEAE
Acrophyllum australe- Woodford to Faulconbridge, 2VCi, local endemic

DILLENIACEAE
Hibbertia hermanniifolia- Bents Basin, Wallacia, 3RCa, disjunct local pop. Nth-limit

EPACRIDACEAE
Epacris sparsa- Avoca Vale, very rare local endemic
Leucopogon fletcheri- Springwood, Blaxlands Ridge, 3RC-, local pop.
Monotoca ledifolia- Sublime Point, Leura, 3RC-, locally restricted with small populations

MYRTACEAE
Eucalyptus benthamii- Nepean R. Wallacia- Camden, Kedumba Ck, 2VCi, local endemic
Eucalyptus burgessiana- Faulconbridge, Linden, 2RCa, local endemic
Leptospermum emarginatum- Nepean River, Penrith; Bents Basin, local pop. Nth-limit

PROTEACEAE
Grevillea longifolia- Lawson-Springwood, 2RC-, disjunct local pop.
Persoonia hirsuta- Springwood-Glenbrook, 3KCi, local pop.

RUBIACEAE
Canthium coprosmoides- Avoca Vale, local pop.
Psychotria loniceroides- Avoca Vale, local pop.

RUTACEAE
Zieria involucrata- Springwood, Burralow Swamp, 2VC-
Zieria murphyi- Tomah Saddle, 2VC-

SOLANACEAE
Cyphanthera scabrella- Glenbrook Gorge, Erskine Ck, Bowen Ck, 2RC-, restricted local endemic

TREMANDRACEAE
Tetratheca neglecta- Yerranderie, 2RC-

MONOCOTYLEDONS

CYPERACEAE
Carex neurochlamys- Avoca Vale local pop., Sth limit

IRIDACEAE
Libertia paniculata- Avoca Vale, local pop.

LOMANDRACEAE
Lomandra fluviatilis- Bents Basin, Nortons Basin, Glenbrook Creek, 3RC-

(pop = population, Sth - southern, Nth = northern; codings from Briggs & Leigh)

Table 15. Major conservation reserves in the area covered by the Penrith 1:100 000 map sheet.

Reserve	Approx area on map sheet (ha)
Agnes Banks Nature Reserve	64
Windsor Downs Nature Reserve	330
Bents Basin State Recreation Area	399
Georges River State Recreation Area	part only
Cattai (incl. Mitchell Park) State Recreation Area	116
Blue Mountains National Park	part only
Wollemi National Park	part only
Castlereagh State Forest (Demonstration Forest)	448

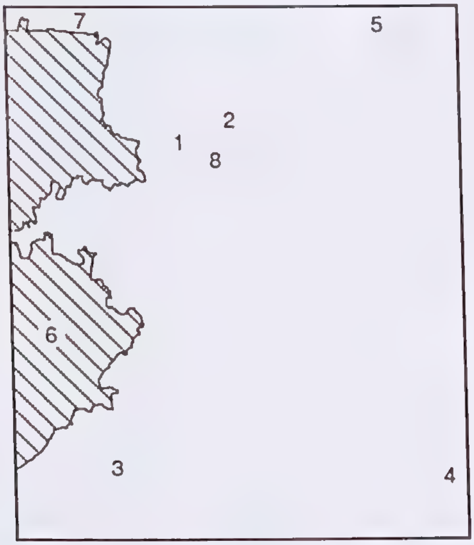


Figure 9. Location of conservation reserves for Penrith map sheet area. 1 Agnes Banks Nature Reserve; 2 Windsor Downs Nature Reserve; 3 Bents Basin State Recreation Area; 4 Georges River State Recreation Area; 5 Cattai State Recreation Area; 6 Blue Mountains National Park (hatched); 7 Wollemi National Park; 8 Castlereagh State Forest.

In particular, the importance of the role of local councils should not be overlooked. The now disparate occurrences of many of the plant species in western Sydney mean that many are not included within the National Parks and Wildlife Service reserves system and occur in small areas under council control (Figure 10).

Whereas local plant populations in the small reserves in the sandstone areas are generally backed up by larger populations in the surrounding National Parks, there are no large reserves for the Wianamatta Shale, Tertiary and Holocene alluvium plant communities of Western Sydney. The potential for future losses in reserves in these areas is therefore of far greater significance. Such areas will gradually become even more fragmented than they are now and the tendency to tidy up wild areas, using lawn mowers, herbicides, etc., along margins, fences, roads, paths, reduces irrevocably a little more of the natural diversity each time .

A long-term trend that should be recognised is the increasing amount and quality of run-off water being directed into remnant natural areas. The addition of nutrient and

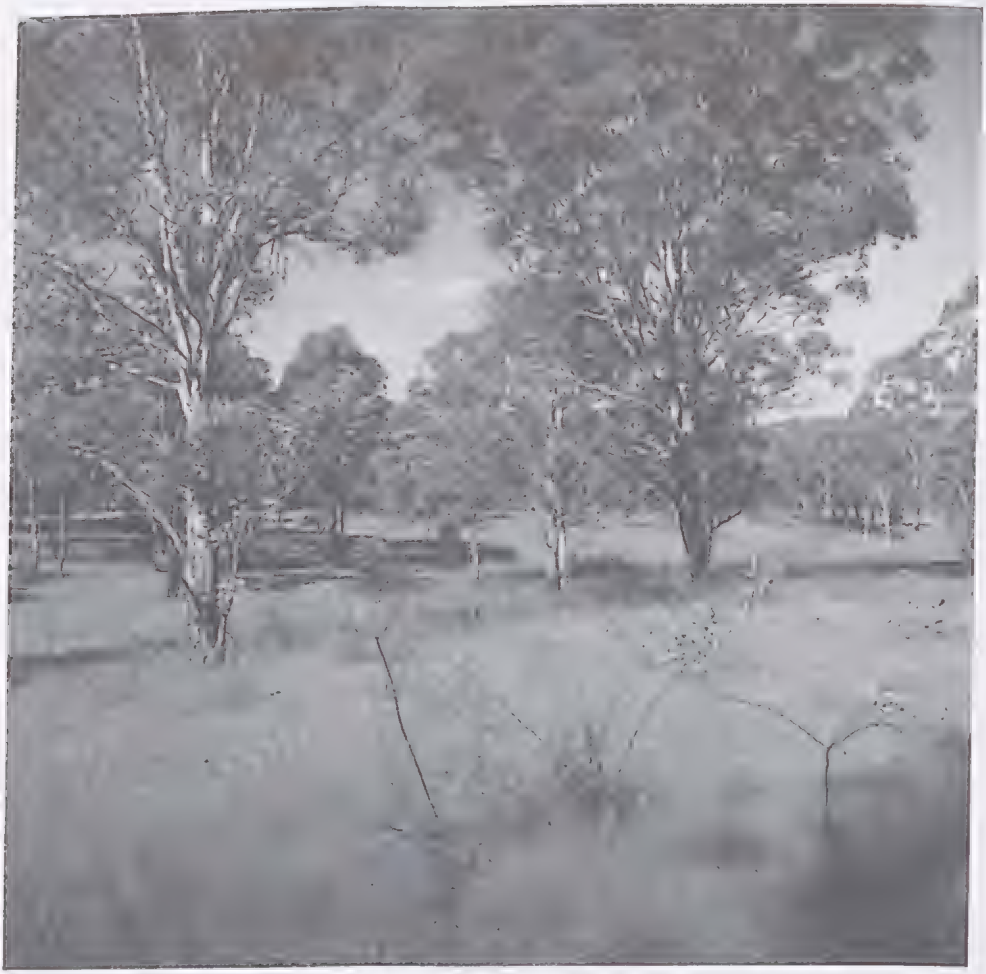


Figure 10. Lansdowne Park contains extensive areas of Cumberland Plain Woodland, many of the species of which respond well to periodic fires. Fortunately it is large enough to support a managed fire regime, despite its suburban context.

promotion of weed invasion is now widely recognised (e.g. Buchanan 1989) and threatens, in particular, the low-nutrient habitats. Increasing volumes with increased nutrients result from the large scale paving of hard surfaces in built-up areas, the loss of trees, the greater use of water in gardens, car washing, sewer discharges, pet excrement (pets may add 3–10 kg/ha/year of phosphorus to suburban areas - Benson & Howell 1990*b*), and the increasing concentration of run-off in fewer creek lines and channels. As discussed earlier, the Cumberland Plain vegetation is adapted to conditions of low rainfall and is therefore capable of sustaining periods of drought. Increased soil moisture, however, is more likely to eliminate native species by favouring rank growing exotic species. Apart from the well publicised dangers of Privet, *Ligustrum* spp. *Lantana camara, Tradescantia albiflora* etc., the spread of Kikuyu, *Pennisetum clandestinum*, is a danger. This grass is being used more frequently in recreation areas and disturbed sites and is a vigorous invader of native bush where the conditions are suitable.

3. Identification of corridors, regeneration and planting

Corridors linking the major conservation reserves and smaller remnants need to be designated and enhanced. The main north-south creek systems, Eastern Creek, South Creek and Kemps Creek, together with the Hawkesbury-Nepean and Georges Rivers should be the skeleton, together with interconnections across catchment divides. Some of these corridors, for example Eastern Creek, are already recognised by the Department of Planning, but plans for encouraging natural tree regeneration and planting need to be developed. Regeneration should be encouraged where residual native vegetation remains as this retains the scientific values of local genetic provenances. Any planting in a natural site should be propagated from local material.

4. Treatment of flood-prone areas and wetlands

Remnant vegetation often survives in floodprone areas. Wetlands, in particular, are important and should be protected from drainage or other alteration. Although such sites are not suitable for urban development, they are highly susceptible to changes and increasing volumes of run-off from adjacent urban areas. In some areas the increased run-off has led to the native creek vegetation being replaced by broad concrete stormwater channels. Since this creekside vegetation is often the only remaining vegetation, its destruction is a major loss of local biodiversity. There may also be cases where wetlands should be rehabilitated. Pitt Town Nature Reserve has been heavily grazed and most native species except for some *Juncus usitatus*, *Carex appressa*, *Triglochin procera* and *Persicaria lapathifolia* have gone. It is an important site for birds and provides scope for rehabilitation.

5. Identification of buffer zones

Because many of the conservation areas and bushland remnants are small and will soon be surrounded by increasingly dense urban populations, buffer zones will be needed and should be developed now. Such areas should be established with appropriate local native trees and shrubs to provide semi-natural bush to take intensive recreational use out of the intact bushland remnants.

6. Maintaining diversity of other wildlife, particularly birds and invertebrates

In areas planned for future urban development, tree planting, where it is appropriate, rather than preservation or regeneration, should be carried out in advance of building, since established trees will greatly enhance the new suburb's environment. Plantings need to recognise the needs of local fauna, particularly birds and invertebrates. Birds of the dry woodlands of western Sydney should be encouraged by planting woodland and forest groves, of local eucalypt species together with local understorey species including grasses and herbs. The use of non-local but colourful species such as grevilleas, whilst suitable for home gardens, should not be used in large-scale plantings as these favour the common garden birds, rather than providing suitable conditions for the specific local birds of western Sydney.

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The natural vegetation of the Balranald – Swan Hill area

J.A. Scott

Abstract

Scott, J.A. (National Herbarium of New South Wales, Royal Botanic Gardens, Sydney, Australia 2000) 1992. The natural vegetation of the Balranald – Swan Hill area. Cunninghamia *2(4): 597–652.* The present-day natural and semi-natural vegetation of the Balranald and the Swan Hill (New South Wales section) 1:250 000 map sheets (south from 34°00'S to the Murray River; 142°30'E to 144°00'E) in semi-arid south western New South Wales is described and mapped. The area is part of the South Western Plains and South Far Western Plains botanical subdivisions. Twenty vegetation communities are recognised including mallee, woodlands of Belah-Rosewood (*Casuarina pauper-Alectryon oleifolius* subsp. *canescens*) and *Callitris*, riverine forest and various chenopod shrublands. Vegetation has been mapped using a combination of aerial photographs, field survey and LANDSAT imagery. The vegetation patterns reflect landform (an east-west transition from the fluvial and lacustrine plains to the aeolian sand dunes) and soil types (heavy clays of the plain to calcareous sands). All vegetation shows disturbance (grazing, clearing and cropping, erosion and weeds). Most plant communities are poorly conserved, with less than half of the communities represented in the 3% of the mapped area currently reserved.

Introduction

Location

The mapped area (south from 34°00'S to the Murray River, 142°30' to 144°00'E) is located in the semi-arid zone of south-western New South Wales. It comprises the Balranald 1:250 000 map sheet (S1 54-12) and the New South Wales section of the Swan Hill 1:250 000 sheet (S1 54-16). This area adjoins the eastern edge of the Mildura sheet which was mapped as part of the Ana Branch - Mildura vegetation map (Fox 1991). This mapping is part of a major project of the Royal Botanic Gardens to map the vegetation of south-western New South Wales.

There are two main rivers in the area (Fig. 1). The Murray River flows from south-east to north-west, forming the southern boundary of New South Wales and of the mapped area. The Murrumbidgee River flows south-west joining the Murray approximately 35 km south-west of the town of Balranald. It also marks in part the boundary between the Central and Western Divisions of New South Wales. South-west of Balranald the division boundary leaves the river, passes through Kyalite, then down the Wakool River to its junction with the Murray River. The greater percentage of the mapped area falls within the Western Division under the tenure of the Western Lands leases.

The main towns are Balranald (population of 1 400) on the Murrumbidgee River and Euston (population of 400) on the Murray River. These towns are linked by the Sturt Highway which runs east-west from Wagga Wagga to South Australia. The main north-south road links Balranald to the Cobb Highway at Ivanhoe in the north. Swan

Hill is the largest centre in the area (population 9 500) located on the Victorian side of the Murray River. The area beyond these towns is sparsely settled. The map covers parts of four shires: Balranald, Wakool, the easternmost edge of Wentworth, and the westernmost edge of Hay. It covers sections of the botanical subdivisions of the South Far Western Plains and South Western Plains, the boundary between the two is through Balranald. The total area of the map sheet is approximately 17 000 km^2.

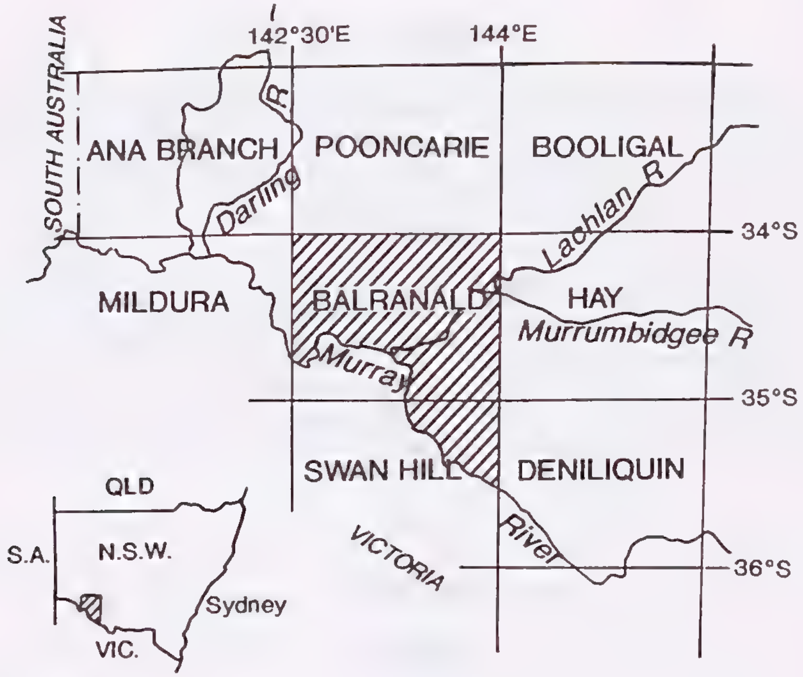

Figure 1. Locality map showing part of the 1:250 000 map grid.

Climate

The climate of the study area is semi-arid. Temperatures are hot in summer and mild in winter (Table 1). The hottest month is January with an average daily temperature range of 16–33°C; the coldest month is July with an average range of 3–16°C recorded at Balranald (Bureau of Meteorology, 1988).

Rainfall is low and highly variable. The mean yearly rainfall, based on 107 years of record, for Balranald is 320 mm, and gradually decreases to the north and west. The rainfall is relatively evenly distributed throughout the year, only slightly higher and more frequent in the winter/spring months of May to October. In the summer months there are occasional heavy rainfalls yielding the higher values for the mean compared to the median. The variation from year to year is high, for example 1973 had 692 mm whilst 1982 had 129 mm (Bureau of Meteorology 1988).

The high evaporation experienced during summer, greatly reduces the availability of moisture to plant growth. June to September is generally the most favourable period for plant growth (Rhodes 1990).

Table 1. Climatic averages for Balranald for temperature (20 years of record) and rainfall (107 years of record) (Bureau of Meteorology 1988).

	J	F	M	A	M	J	J	A	S	O	N	D
Daily Max. Temp. (°C)	32.6	32.5	29.0	24.2	19.5	16.1	15.8	17.5	20.1	23.9	27.4	30.5
Daily Min. Temp. (°C)	16.4	16.6	13.7	9.9	7.0	3.8	3.2	4.7	6.7	9.8	12.2	14.2
Rainfall (mm)												
Mean	21	24	24	24	32	30	25	30	29	32	26	23
Median	9	12	16	17	28	25	22	26	24	23	17	15
Rain days (Mean no.)	3	3	3	4	6	7	7	8	6	6	4	3

Geology and geomorphology

The mapped area falls within the Murray Geological Basin (Fig. 2), formed during the Tertiary period approximately 60 million years ago. The pre-Tertiary geology described in Pels (1969) and summarised in Fox (1991) indicates a long period of sedimentation underlying the basin. There are no rock outcrops within the mapped area unlike the edge of the basin in the Darnick and Manfred Ranges to the north-west.

Sedimentation in the Tertiary provided much of the source-material for the geomorphological processes in the Quaternary which shaped the landscape seen today. It also apparently controls some of the geomorphic features such as drainage and the presence of major aquifers (Soil Conservation Service 1990). Within the mapped area the landscape history can be best described in three sections according to the geomorphological processes responsible for their formation.

The western half of the Murray Basin encompassed the Murravian Gulf (Fig. 2) which was shaped and infilled largely with marine sediments in the late Tertiary. At its maximum (during Miocene time) the sea extended as far east as Balranald where marine sediments containing abundant fossils have been found at depths of 150–270 m (Pels 1969). Its regression left ridges of Parilla Sand (Firman as cited by Bowler & Magee 1978). Further sedimentation took place when most of this area was again inundated, this time with fresh water from the damming of the Murray River forming Lake Bungunnia. This drained out approximately 700 000 years ago (Bowler 1980). During the Quaternary the deposits were reworked by the wind into dunefields and sandplains of the Woorinen formation (Lawrence 1966). This aeolian landscape has its easternmost edge in a line approximately north-south through Balranald.

East of Balranald is the riverine plain. This is a fluviatile landscape deposited by the system of prior streams that eroded the Murrumbidgee and Lachlan valleys in the late Pliocene and Pleistocene times (Woolley 1978, Butler 1950). The present surface of the plain represents the final phase of prior stream deposition that took place in the Quaternary and is regarded as a relic landform of this age (Pels 1969). The raised stream beds and levee banks of the last of the prior stream channels can be seen on the plain today as slight sandy rises. They are more easily seen from the air. These rivers carried greater discharges than the present rivers, as evident from the greater channel width and longer meander wavelengths. Clays were deposited from the prior streams when water was isolated beyond its levees on extensive floodplains (Pels 1969). The present-day rivers, the Murrumbidgee, Lachlan and Murray which meander across the landscape, have not been responsible for the topography of the plain (Pels 1969).

The transition zone between these two distinctive landscapes, fluviatile in the east and aeolian to the west, runs through the centre of the mapped area (Fig. 3). It marks the transition from riverine sources of sediment from the east to the marine and littoral sources of sediments from the west (Mabbutt 1980). This boundary has fluctuated over time and is important in providing landform evidence of climatic change (Mabbutt 1980). The landforms are possibly of riverine or lacustrine origin with a veneer of aeolian material (Scriven 1988*b*). Fluviatile sediments are thin, and ancient lunettes formed in the Tertiary period are often exposed (Pels 1969). The two processes, aeolian and fluvial, have combined to produce lake basins that were active in a

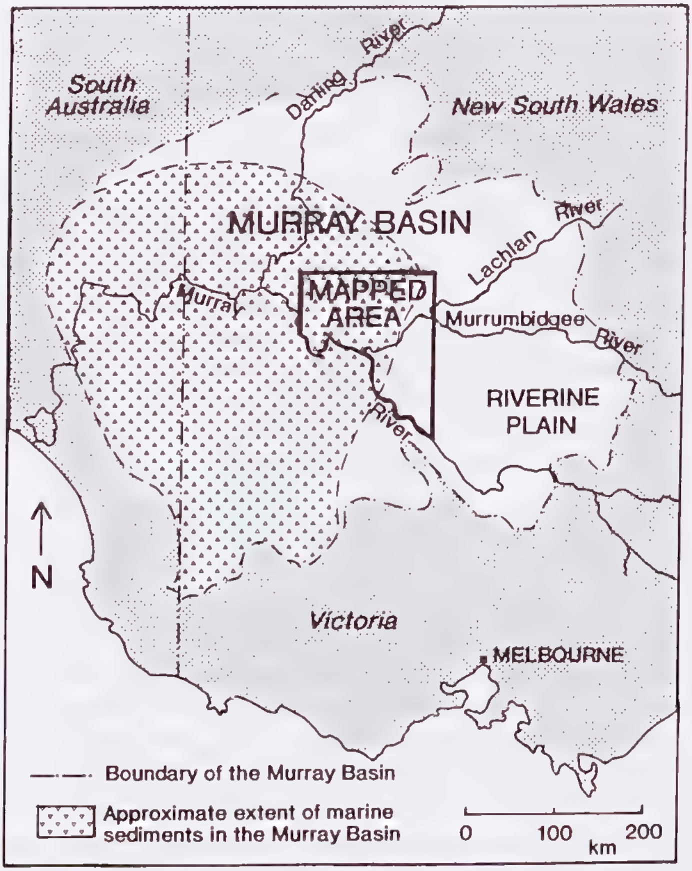

Figure 2. Map of south-eastern Australia showing the location of the mapped area within the Murray Basin. Based on a map by Lawrence (1966).

wet phase of the Pleistocene 50 000 to 25 000 years ago (Bowler & Magee 1978). A drying-out phase followed, with its peak in the last glacial period 18 000 to 16 000 years before present. During this time dune building occurred on the eastern edges of each lake, forming lunettes. These are still present today.

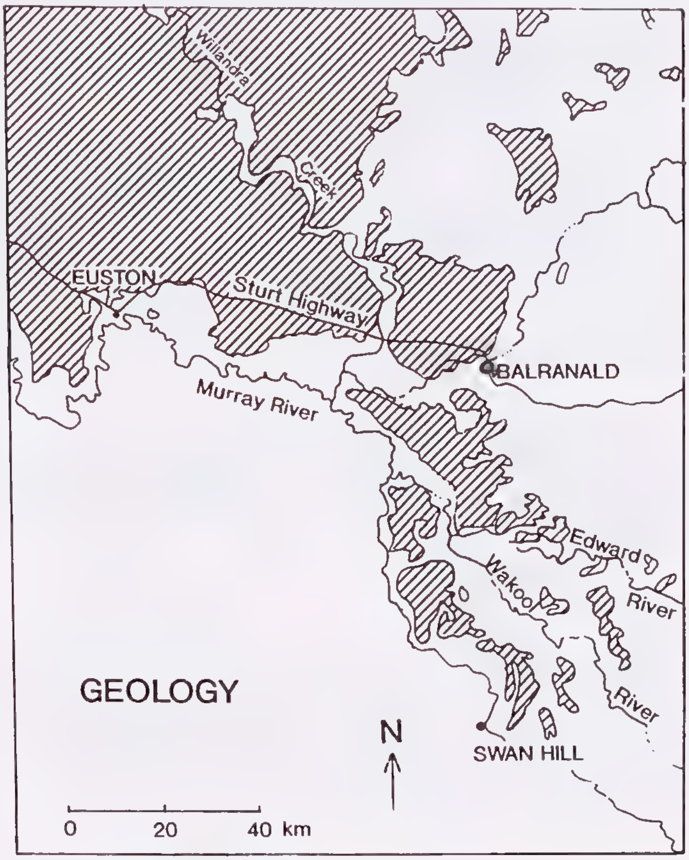

Figure 3. The geology of the mapped area based on a map by the Soil Conservation Service of New South Wales (1990). Hatched areas are largely aeolian, flat to gently undulating plains and dunes of red and red-brown clayey sands and loams. Unhatched areas are flat alluvial and lacustrine deposits of gravel, sand, silt and clay.

Present landforms

Rivers

The major rivers flowing through the area are the Murray and the Murrumbidgee, which enters the Murray 35 km south-west of Balranald. The Edward and Wakool Rivers, which branch near Deniliquin, flow to the west in parallel courses and reunite near Kyalite before entering the Murray just upstream from the Murrumbidgee. The rivers carry water from the tablelands and slopes in the east across the Riverine Plain where there is limited contribution from runoff. The Great Cumbung Swamp occurs on the Lachlan River just north of where it enters the Murrumbidgee on the easternmost side of the mapped area. It is one of the most significant inland wetlands in NSW (Pressey *et al.* 1984).

Dunefields

The linear dunes are relic features stabilised for the last 15 000 years by vegetative cover. They occur on the western half of the map-sheet area forming a series of parallel rounded ridges with a west-east orientation. These dunes vary in height from 2 m to 6 m from crest to swale, spaced with approximately 0.2–1.2 km between adjacent dune crests, and are commonly 0.5–1 km in length, sometimes to 3 km in the west. Their average composition is 7–10% clay content and 5% calcium carbonate, with the highest values in the swales and the lowest on the dune crests (Bowler & Magee 1978). The swales contain fine-grained clay loam, often with limestone nodules.

The dunefields are a part of the Woorinen Formation (Lawrence 1980), which extends into northern Victoria. The sand content of these dunes is thought to have originated from the Parilla sands deposited with the retreat of the Murravian Gulf in the upper Miocene to lower Pliocene (Bowler & Magee 1978, Lawrence 1980, Semple 1990). The clays are thought to have originated from the lacustrine sediments of the Quaternary, whilst the calcite from cyclic salts and as dust derived from shells exposed on the South Australian coastline at times of low sea level (Lawrence 1980). The dunes become less frequent in their distribution from west to east, becoming absent on the sandplains.

North of Lake Benanee lies a broad flattish NW-SE aligned area of non-linear sand dunes (Fig. 4). Similar ridges in south-west Victoria and South Australia are postulated to be relic Tertiary shoreline features formed by the retreat of the sea in the Late Tertiary (Bowler & Magee 1978, Blackburn 1962), depositing Parilla Sands (Macumber 1969, Bowler & Magee 1978, Lawrence 1980).

Sandplains

Sandplains occur in the middle of the map-sheet area where the aeolian sand cover is thinner, in the zone of transition between the dunefields to the west and the Riverine plain in the east. They support Mallee, and Belah-Rosewood woodland (*Casuarina pauper* with *Alectryon oleifolius* subsp. *canescens*). The land is flat and there are generally no dunes. The clay and calcium content is higher than in the dunes, but the origin of the sediments is similar.

Lakes

The numerous lakes in the area are relic features relating to hydrologic events of the late Pleistocene (Bowler & Magee 1978). They were full when the climate was wetter 50 000 to 25 000 years ago. At this time the lakes of the Willandra system to the north overflowed through an outlet channel, still evident today west of Balranald, to join the Murrumbidgee River. The Prungle Lakes are the southernmost of this system and part of the Willandra World Heritage area. The lakes nearer Balranald also date from this time; their water source was probably from an elevated water-table across the region (Pressey *et al.* 1984).

In appearance, the lakes are typically smooth and elliptical, often kidney-shaped in outline with the long axis oriented north-south. They vary in size from 2 km long (Moonlight Lake) to 10 km long (Pitarpunga Lake). Most lake basins are dry although some near the floodplains of the Murray and Murrumbidgee Rivers are intermittently filled when the rivers are flooded. Others are now artifically filled for use as water storage basins. The sediments on the lake floors consist of slightly saline calcareous clays, with silts and sands more prominent on the eastern downwind margins (Mabbutt *et al.* 1982).

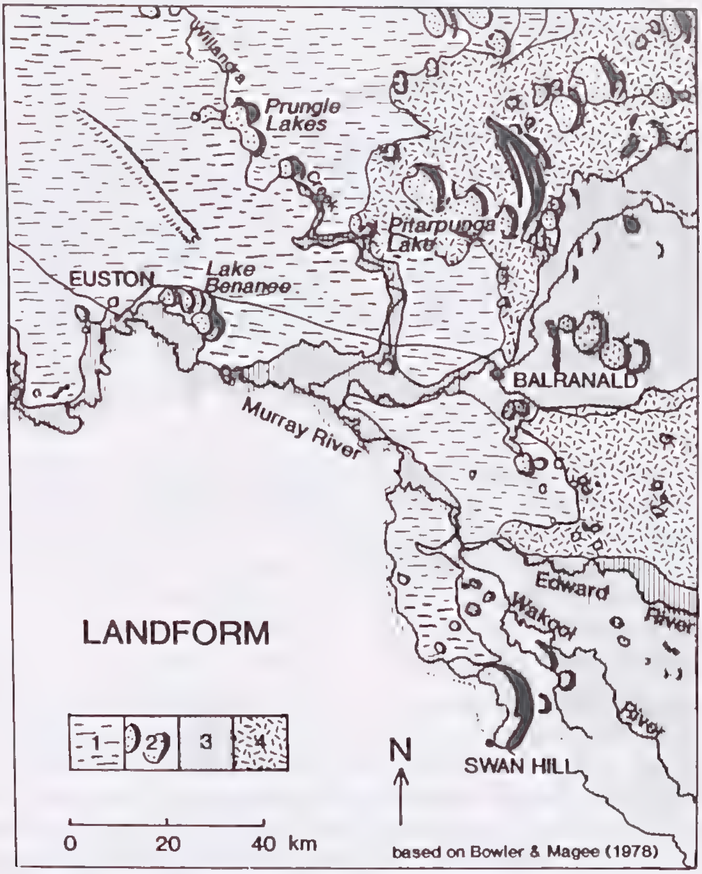

Figure 4. Landform features and geomorphology of the mapped area. Aeolian: 1. linear dunes and sand plain, 2. lunettes on eastern side of lakes. Fluvial: 3. low level alluvium, 4. clay plain. Based on a map by Bowler and Magee (1978).

Lunettes

Lunettes are the smooth cresent-shaped dunes on the eastern edge of the lakes. They are thought to be formed 40 000 to 15 000 years ago with the most intensive phase at the peak of the last glaciation 18 000 to 16 000 years before present (Bowler 1976). At this time the climate was drier and slightly cooler with temperatures several degrees below their present mean (Bowler 1980). The lunette building process occurred as a result of the seasonal flooding and drying out of the lake leaving a salt residue on the lake bed which helps break up the clay soil. The clay particles are then blown by unidirectional winds and deposited to form a dune (Bowler 1980). The resulting lunettes are composed predominantly of clayey sands, gypseous clays and, as in Prungle Lake, almost pure gypsum (Australian Heritage Commission 1980). The size of the lunette is proportional to the size of the lake.

Riverine plain

The western edge of the riverine plain covers the eastern quarter of the map sheet. The plain, consisting of Quaternary alluvium, is mostly treeless except for the forests and woodlands along the rivers, and the woodlands on the levees and raised beds of prior streams. The soils are mainly heavy clays and the dominant vegetation communities are chenopod shrublands.

Prior streams and source-bordering dunes

Prior streams (Butler 1950) were major river systems active in the Pleistocene which deposited sediment forming the present-day Riverine Plain. The stream traces, seen on the present landscape most clearly from the air, cross the plain and fragment as they near the transition zone on the western edge of the plain. They appear on the ground as a change to redder sandier soil and/or slight sandy rises, representing the old source-bordering dunes and raised stream bed. South-east of Balranald the remains of one such prior stream is seen as red sandy rises across the landscape with remnants of *Callitris* mixed woodland.

Soils

There is a high correlation between soil type and landform. The following soil descriptions have been taken from Charman and Murphy (1991), Northcote (1980) and from the soil map for Balranald (Eldridge 1985). Much of this area is covered in a fine-grained sediment known as parna, which covers the plain and swales of the dunefields (Butler 1956).

Plains of calcareous earths

The most extensive soil type is grey-brown loamy calcareous earths, often with exposed cemented carbonate at the surface. They are found between and to the north of Balranald and Euston. Isolated sandy dunes of low relief are associated with flats of various duplex soils. To the east of Balranald calcareous earths, transitional hard red and yellow duplex soils and areas of grey cracking clays are present. Many of these areas have lost their topsoil through wind and water erosion (in the case of duplex soils), or winnowing of the finer particles (in the case of the calcareous earths) (Eldridge 1985).

Dunefields of calcareous and brownish sands

Linear dunes of deep brownish sands in association with calcareous sands are found in the west and north-west of the map sheet. These support mallee vegetation. Plains and swales of brown calcareous earths and assorted duplex soils are associated with these dunes.

Plains of grey cracking clays

Self-mulching grey and yellow-grey cracking clays are associated with the rivers and floodplains. East of Balranald there is a mosaic of grey cracking clays and hard duplex soils (red-brown earths). The remains of prior streams south-east of Balranald have typically scalded margins and levees, and beds of shallow, calcareous sands. Their source-bordering dunes are composed of deep, calcareous and siliceous sands. The lunettes and rises consist of yellow duplex soils and granulated clays.

Dunes with sands and calcareous earths are highly susceptible to wind erosion if vegetative cover is removed (Semple 1989). In contrast, high clay content of the riverine plain soils reduces their susceptability to erosion.

Previous vegetation surveys

General surveys

The survey and mapping by Beadle (1948), at a scale of 1 inch: 16 miles, is the most comprehensive survey covering the whole of western New South Wales. Beadle delineated 22 major vegetation associations for the Western Division, five of which occur within the mapped area. Mallee *Eucalyptus oleosa* (referring chiefly to *E. socialis*) - *Eucalyptus dumosa* association covers much of the western half of the study area on dunefields of aeolian sandy soils. Patches of *Casuarina - Alectryon* [*Heterodendrum*] association (Belah and Rosewood) occur throughout but are more extensive to the north of the mapped area. Shrublands are important in the east, the main ones being *Maireana pyramidata - Maireana sedifolia* [*Kochia pyramidata - K. sedifolia*] association (Bluebush) and *Atriplex vesicaria* [*Atriplex vesicarium*] association (Saltbush). The river floodplains in the east and along the Murray River support forests of *Eucalyptus largiflorens* association (Black Box) [*Eucalyptus bicolor*].

Noy-Meir (1971, 1974, 1980) has produced an unpublished map of south-western New South Wales at a scale 1:1 000 000. Plants of Western New South Wales (Cunningham *et al.* 1981) and the Flora of New South Wales (Harden 1990, 1991) are the main reference books for the identification of plant species. The N.S.W. Soil Conservation Service also has a range of 'Technical Manuals' which contain a review of literature and other souces of information for various vegetation types. That Service also produced a number of 'Working Documents', which give a literature review of specific chenopod species.

Surveys specific to the Balranald – Swan Hill map area

The present distribution and status of the vegetation of the riverine forests along the Murray River, its anabranches, and the Edward and Wakool system, were assessed in a detailed survey for the Murray - Darling Basin Commission (Margules and Partners *et al.* 1990). The 1:50 000 maps produced from this survey were incorporated in this mapping project.

The maps produced from a survey of the confluence of the Lachlan with the Murrumbidgee rivers by Pressey *et al.* (1984) were also used. This study covers 88 000 ha, of which approximately 90% is on the Balranald sheet, and the remainder on the adjacent Hay sheet.

Located on the western boundary of the Balranald map sheet is Mallee Cliffs National Park. A vegetation map of the Park at 1:50 000 was produced by Morcom and Westbrooke (1990) with descriptions of the various plant communities. Approximately 90% of the 58 000 ha park is located on the Balranald sheet.

An extensive study of the mallee lands of north western Victoria (Land Conservation Council of Victoria 1987) included a vegetation map at a scale of 1:250 000. Their close proximity allows comparisons to be made between the Victorian mallee and the mallee in NSW.

The N.S.W. Soil Conservation Service has produced a series of Land Systems maps for the Western Division. The vegetation component of 22 land systems is described briefly for the Balranald 1:250 000 map sheet (Walker 1991).

Table 2. Map unit, main species and structure for plant communities shown on Balranald – Swan Hill 1:250 000 map sheet. Where communities occupy significant areas of the adjacent Ana Branch – Mildura map sheet, equivalent numbers used by Fox (1991) are given.

No.	Plant community	Main species	Structure (*Specht 1981 **Walker & Hopkins 1990)	Fox No.
1	Riverine Forest	*Eucalyptus camaldulensis*	open forest * & **	1
2	Black Box Woodland	*Eucalyptus largiflorens*	woodland *; woodland - open woodland **	2
3a	Mallee on Irregular Dunefield	*Eucalyptus dumosa, E.socialis, E. costata, E. leptophylla, Triodia scariosa*	tall shrubland *; mallee shrubland - open mallee shrubland **	
3b	Dune-Crest Mallee	*Eucalyptus dumosa, E. socialis, Triodia scariosa*	tall shrubland *; mallee shrubland - open mallee shrubland **	3
3c	Swale Mallee	*Eucalyptus dumosa, E. socialis, E. oleosa, E. gracilis*	tall shrubland *; mallee shrubland - open mallee shrubland **	
3d	Sandplain Mallee	*Eucalyptus dumosa, E. oleosa*	tall shrubland *; mallee shrubland - mallee woodland **	
4	Belah-Rosewood	*Casuarina pauper, Alectryon oleifolius* subsp. *canescens*	woodland *; open woodland - isolated clumps **	4
8	Black Bluebush	*Maireana pyramidata*	low - low-open shrubland *; open - sparse chenopod shrubland **	8
9	Pearl Bluebush	*Maireana sedifolia*	low shrubland *; open - sparse chenopod shrubland **	9
11	Bladder Saltbush	*Atriplex vesicaria, Sclerostegia tenuis*	low shrubland *; open - sparse chenopod shrubland **	11
13	Canegrass	*Eragrostis australasica*	grassland * & **	13
16	*Callitris* Mixed Woodland	*Callitris glaucophylla, Hakea tephrosperma, Hakea leucoptera*	open woodland *; open woodland - isolated trees **	
17	*Acacia melvillei* Woodland	*Acacia melvillei*	tall shrubland - low woodland *; open woodland - open shrubland **	
18	Lignum	*Muehlenbeckia florulenta*	open scrub *; shrubland - open shrubland **	
19	Old Man Saltbush	*Atriplex nummularia*	low shrubland *; open - sparse chenopod shrubland **	
20	Bull Oak	*Allocasuarina luehmannii*	open woodland *; isolated plants **	
21	Cotton-bush	*Maireana aphylla*	low shrubland *; open - sparse chenopod shrubland **	
22	Dillon bush	*Nitraria billardieri*	low open shrubland *; sparse shrubland **	
23	Great Cumbung Swamp	*Phragmites australis* *Senecio cunninghamii*	closed-open herbland *; closed-open grassland/ forbland **	
OA	Open Areas	various shrubs & grasses	low open shrubland *; sparse chenopod shrubland**	

Methods

This project is part of an ongoing vegetation mapping project of south western New South Wales. Methodology is similar to that for Fox (1991). The best available aerial photography is provided by air photomosaics 1961 to 1970 (NSW Dept of Lands) at 1:50 000. These were used to distinguish different vegetation units. Boundaries were marked directly onto the photomosaics. An initial field survey enabled names to be assigned to the vegetation units. These were then reduced and transferred to 1:100 000 topographic maps, which were used as provisional maps. The term 'community' is used for the basic vegetation unit describing areas with similar structural and floristic characteristics.

The provisional maps were field-checked. Twenty-one days of field work during 1990–1991 made it possible to check the different vegetation communities. Notes were taken on the soil type, landform, degree of disturbance of the vegetation and vegetation structure at localities over the whole of the map sheet. For some of the sites a measured area of 0.2 ha (100 m by 20 m) was thoroughly searched and all vascular plants recorded. Lignum (*Muehlenbeckia florulenta*) (community 18), and Great Cumbung Swamp (*Phragmites australis - Senecio cunninghamii*) (community 23), were not sampled due to limited access but information was available from Pressey *et al.* (1984). Areas for which surveys already exist were not sampled as extensively.

Only present-day vegetation is mapped. A combination of field notes with recent (1991) LANDSAT images at 1:250 000 were used to delineate cleared mallee and woodlands. Where possible the pre-clearing vegetation type has been indicated. Some patches of natural vegetation may be present within the areas marked as cleared and along roadsides. These may be important but could not be mapped at this scale. LANDSAT was also useful in defining structurally variable communities such as community 4: Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) woodland. The level of disturbance in the chenopod shrublands was variable and could not be consistently defined from the images.

Surveys for the Lowbidgee (Pressey *et al.* 1984), the Murray River (Margules and Partners *et al.* 1990), and Mallee Cliffs National Park (Morcom and Westbrooke 1990), all at 1:50 000 were referred to in compiling this map.

Many of the vegetation units also occur on the adjacent Ana Branch - Mildura map sheet to the west (Fox 1991). There are, however, slight differences in the numbering of the communities in this survey from that of Fox's survey (Table 2). In addition, the structural classification system of Walker and Hopkins (1990) has been used, as well as Specht (1981).

Within any one community, patches of other communities may occur, for example, patches of mallee in the Belah-Rosewood unit. The dominant community has been indicated on the map.

Botanical names used are those currently recognised at the National Herbarium of New South Wales.

Results

Twenty plant communities are recognised. The main structural formations are mallee shrublands, Belah-Rosewood woodland (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*), mixed woodland of *Callitris* and various chenopod shrublands. Open-forest of *Eucalyptus camaldulensis* occurs along the rivers and open-woodland of *Eucalyptus largiflorens* occurs on the periodically flooded river flats.

The communities described are mostly based on perennial species. Annuals and short-lived perennials vary with seasonal and year-to-year changes (details are given in the 'discussion' section).

A species list for the mapped area is given in Appendix 1. It has been derived from field observations and published lists.

Description of map units shown on the Balranald - Swan Hill sheet

Structure: Specht (1981) = * ; Walker and Hopkins (1990) = **

* When placed before a species name, indicates the species is exotic.

Map unit 1: Riverine Forest

Structure: open forest * & **

Characteristic species: *Eucalyptus camaldulensis* (River Red Gum)

Associated species: *Muehlenbeckia florulenta, Wahlenbergia fluminalis, Paspalidium jubiflorum, Acacia stenophylla, Eucalyptus largiflorens, Cynodon dactylon, Ranunculus lappaceus, Brachycome basaltica* var. *gracilis.*

On the extensive floodplain of the Murrumbidgee River two subunits have been described by Pressey *et al.* (1984).

Levees: *Eucalyptus camaldulensis, Carex appressa, Paspalidium jubiflorum, Wahlenbergia fluminalis,* Cirsium vulgare, *Sonchus oleraceus, Pratia concolor.*

Floodplain: *Eucalyptus camaldulensis, Marsilea drummondii, Phragmites australis, Eragrostis australasica, Centipeda minima, Pratia concolor, Ranunculus lappaceus, Chenopodium nitrariaceum, Atriplex nummularia.*

Soils: levees of grey, massive, non-cracking clays; at low elevations strongly gilgaied, grey self-mulching clays to massive non-cracking clays near the top of the floodplain (Pressey *et al.* 1984).

Occurrence: This community is found on the banks nearest the channels of the major rivers and creeks throughout the region, and on low-lying flats subject to flooding. The largest area of this community is found in the Lowbidgee District along the Murrumbidgee River. The densest stands of this community are along the banks nearest the river channels (Fig. 5). Extensive areas on the flats have a more 'open woodland' structure. For the length of the Murrumbidgee River within the mapped area, Black Box (*Eucalyptus largiflorens*) usually occurs as an adjacent community (2) on the floodplain flats. On parts of the Murray River the floodplain is much narrower and often the River Red Gum forest is abruptly bounded by higher ground of red/brown earths supporting mallee or *Callitris* mixed woodland, much of which has been cleared. This is most apparent along the stretch of the Murray River between the points of entry of the Wakool and Murrummbidgee Rivers.

Comments: The main tree species, *Eucalyptus camaldulensis*, is the tallest tree species in the area and forms the only 'forest' type vegetation. Inundation of varying frequency and duration is important for the survival of this species (Somerville 1988). It often occurs near Black Box (*Eucalyptus largiflorens*) which occupies slightly higher ground on the floodplain a distance from the channel, where flooding is less frequent.

Most of these forests have been logged and grazed at various times. Those most disturbed by grazing had very little ground cover and much bare earth and leaf litter at the time of the survey.

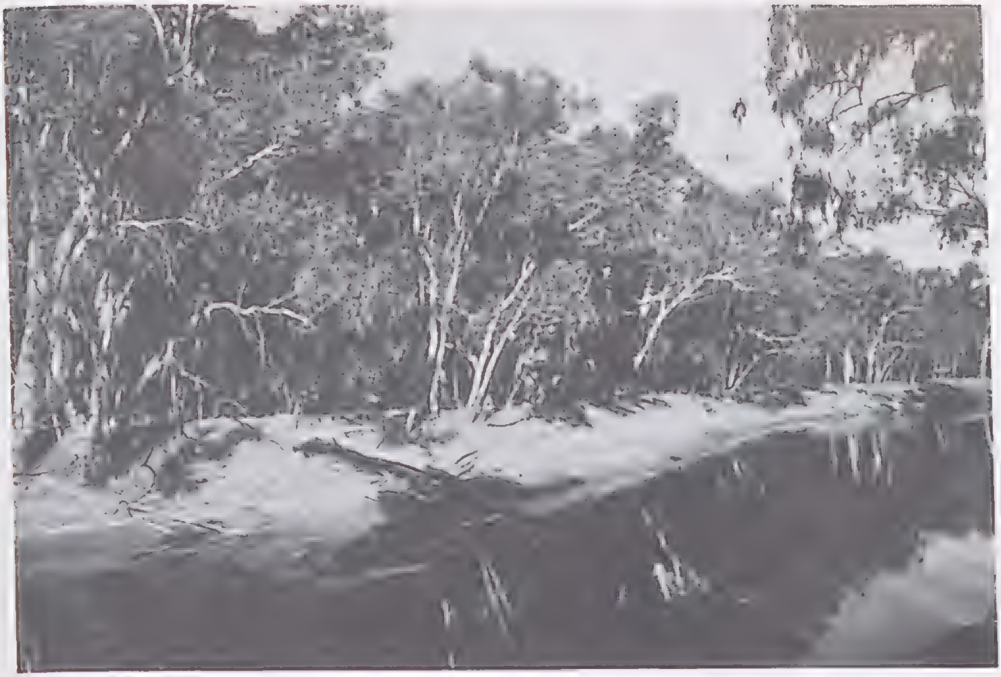

Figure 5. River Red Gum forest (*Eucalyptus camaldulensis*) along the banks of a back-water channel of the Murrumbidgee River, near Redbank Weir.

Map unit 2: Black Box

Structure: woodland *, woodland - open woodland **

Characteristic species: *Eucalyptus largiflorens*

Associated species: *Chenopodium nitrariaceum, Atriplex nummularia, Muehlenbeckia florulenta, Enchylaena tomentosa, Einadia nutans, Sclerolaena tricuspis*, often with *Chamaesyce drummondii, Atriplex lindleyi.*

Soils: Grey clays rarely cracking and with a flat or gently undulating surface.

Occurrence: Throughout the region on the uppermost level of the floodplain; beyond the floodplain it may occur in depressions along creeks, drains and old stream beds (e.g. Box Creek), and fringing ephemeral lakes (Fig. 6.). Examples of this community include Yanga Nature Reserve, the floodplain just west of Euston on the south side of the Sturt Highway, and ringing many of the lakes such as Lake Marimley, Lake Talbetts, Harveys Lake and Chillichil Lake.

Comments: Black Box woodland occurs on the floodplain of the major rivers usually beyond the River Red Gum forest. These areas are at the upper levels of the floodplain where flooding is less frequent. It also occurs along creek lines and is often seen forming a line of trees marking an intermittent or permanent creek. Areas of impeded drainage amongst other vegetation units ranging from mallee to shrublands may also support Black Box, but often as an isolated tree or group of trees. These areas, often too small to map, are most common in the region of the prior stream remains southeast of Balranald. The understorey here was often similar to the surrounding vegetation community. Yanga Nature Reserve consists almost entirely of this community. It has a more diverse understorey with the most abundant species in the Chenopodiaceae, Asteraceae and Poaceae. Within this community at Yanga are open areas of higher ground with grasses and *Maireana pyramidata* shrubland. Along the drainage channels are Lignum (*Muehlenbeckia florulenta*) and *Chenopodium nitrariaceum*.

Chenopodium nitrariaceum is closely associated with Black Box as an understorey species, but can also extend beyond the tree line forming a shrubland. This may be seen east of Perekerten where it dominates a lake-bed, and in smaller patches south-east of Balranald.

Some areas of this unit showed only a scattered distribution of trees, for example in the Swan Hill section of the map. These areas have probably been cleared or thinned in the past.

A less common variant of this community consists of a *Eucalyptus largiflorens* overstorey with the understorey dominated by *Melaleuca lanceolata*. This subunit was restricted to a few localities within the mapped area, the main one of which is located on the Euston-Prungle road just north of Euston. Here the other understorey species are more typical of the adjacent woodland of Belah-Rosewood, (*Casuarina pauper-Alectryon oleifolius* subsp. *canescens*), with *Callitris glaucophylla* into which this community grades. They include *Olearia pimeleoides, Dodonaea viscosa* subsp. *angustissima*, the chenopods *Enchylaena tomentosa, Einadia nutans* and *Chenopodium desertorum* subsp. *microphyllum*, with many annuals including three species of *Vittadinia*: *V. gracilis, V. cervicularis* var. *cervicularis* and *V. dissecta* var. *hirta*. It is located on higher ground consisting of brown-red loam soil between the floodplain associated with the Murray River and the mallee country. Two smaller populations occur within the mapped area, one on the edge of the Murrumbidgee floodplain on the road to Red Bank Weir, and the other on the southern edge of Pitarpunga Lake.

A small population of *Eucalyptus intertexta* is located to the west of Euston, adjacent to the Black Box community. The area lies between the Black Box woodland, on the floodplain, and the mallee, on the raised sand country.

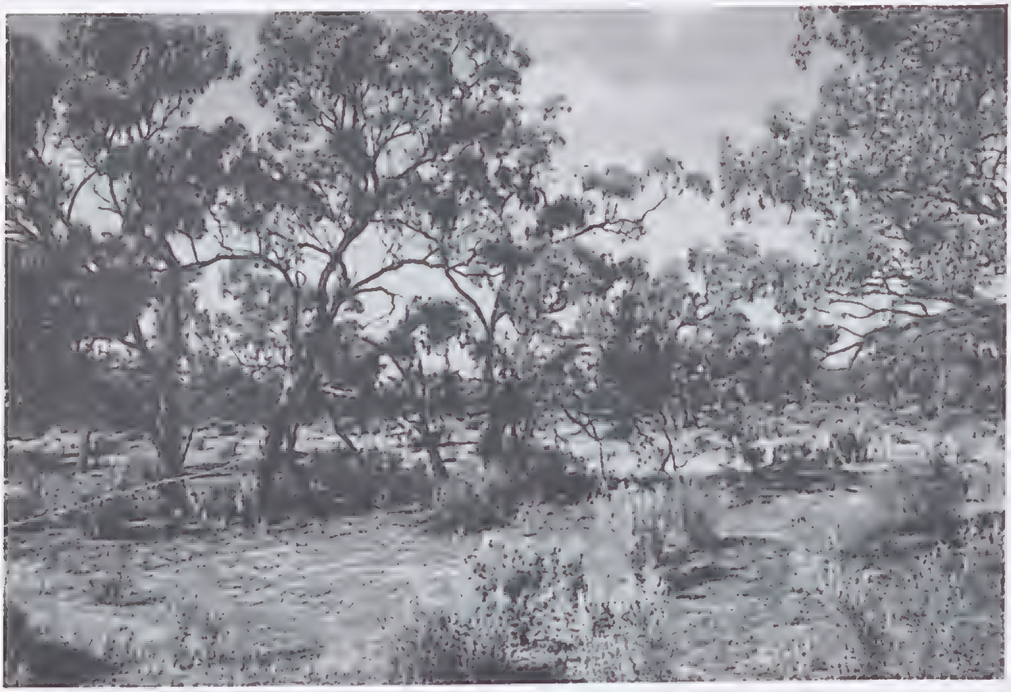

Figure 6. Floodplain with Black Box (*Eucalyptus largiflorens*) and Old Man Saltbush (*Atriplex nummularia*) in the foreground.

Map unit 3: Mallee

3a. Mallee on Irregular Dunefield

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species: *Eucalyptus dumosa, E. socialis, E. costata, E. leptophylla, E. oleosa, Triodia scariosa*

Associated species: *Olearia muelleri, Grevillea huegelii, Acacia colletioides, Bossiaea walkeri.*

Soils: Deep red-brown siliceous sands (Eldridge 1985).

Occurrence: The only area is in Mallee Cliffs National Park just north of Chalky Tank; it occurs more commonly to the north on the Pooncarie map.

Comments: This community consists of very even low mallee. The trees are approximately 3 m high, with many thin stems arising from the lignotubers ('whipstick' mallee, Beadle 1948). Geomorphological evidence suggests the dune landform supporting this vegetation may consist of Parilla sands, laid down when the Murravian Gulf was a marine environment between 6 and 26 million years ago (Blakers & Macmillan 1988). Even when buried, the sands influence the plant communities by altering the moisture regime of the soil.

3b. Dune-Crest Mallee

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species: *Eucalyptus socialis, E. dumosa, E. gracilis, Triodia scariosa.*

Associated species: *Olearia pimeleoides, Acacia colletioides, Dodonaea viscosa* subsp. *angustissima, Eremophila glabra, Eucalyptus costata, Senna artemisioides* subsp. *filifolia, Chenopodium curvispicatum, Maireana pentatropis, Westringia rigida, Myoporum platycarpum,* occasional *Callitris verrucosa.*

Soils: Deep brown calcareous and siliceous sands (Eldridge 1985).

Occurrence: Throughout the western half of the map sheet on the aeolian sands. In the north-west it is associated with Belah-Rosewood woodland (community 4) that occurs in the swales. This pattern is more common on the Ana Branch map sheet in the north-west, mapped as unit 5 by Fox (1991). Fig. 7

Comments: This community is fairly widespread in the west but varies in the frequency of dunes, which is higher on the western boundary of the map on both sides of the the Sturt Highway where the swales support community 3c. Further east the frequency decreases as the Sandplain Mallee community dominates. There are remnants of Dune-Crest Mallee found in the Kyalite area with community 3c in the swales.

3c. Swale Mallee.

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species: Eu*calyptus dumosa, E. socialis, E. oleosa, E. gracilis*

Associated species: *Enchylaena tomentosa, Maireana pentatropis, Maireana sclerolaenoides, Atriplex stipitata, Zygophyllum apiculatum, Zygophyllum aurantiacum, Westringia rigida, Senna artemisioides* subsp. *filifolia, Sclerolaena obliquicuspis, Acacia colletioides, Dodonaea viscosa* subsp. *angustissima.*

Soils: Brown loamy calcareous earths (Eldridge 1985).

Occurrence: Throughout the dune-fields on the western half of the map sheet associated with the Dune-Crest Mallee community of 3b, particularly south of the mosaic pattern of 3b/4. Isolated Belah (*Casuarina pauper*) occurs in some of the swales.

Comments: *Eucalyptus oleosa* tends to occur on the lowest areas of the swales, with *Eucalyptus socialis* on the dune flanks (Hill 1989). The trees are usually larger than

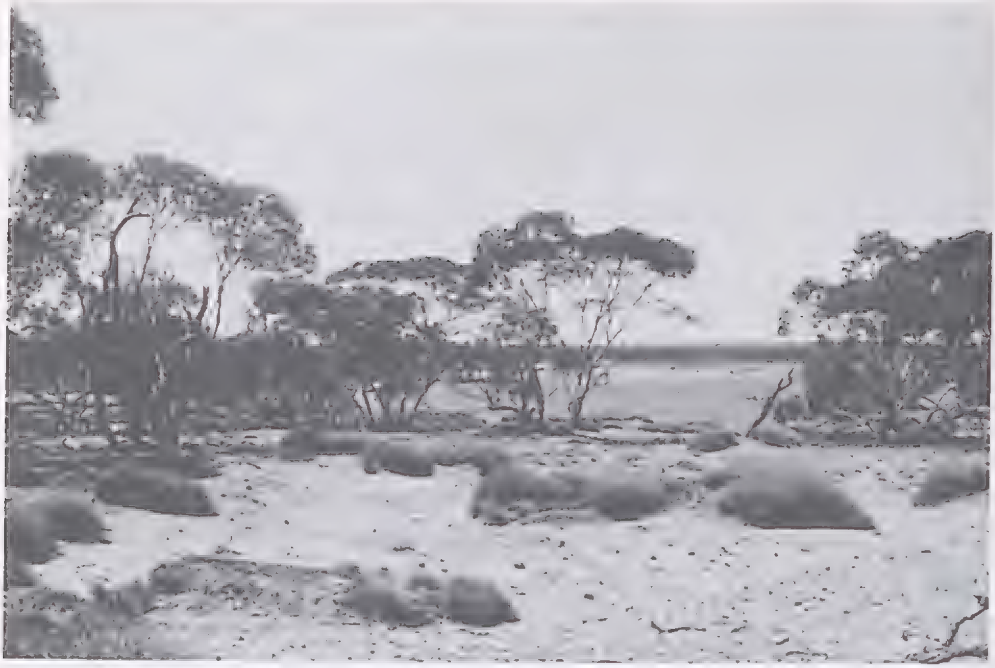

Figure 7. Disturbed sandy rise with Dune-Crest Mallee. Clumps of *Triodia scariosa* in the foreground.

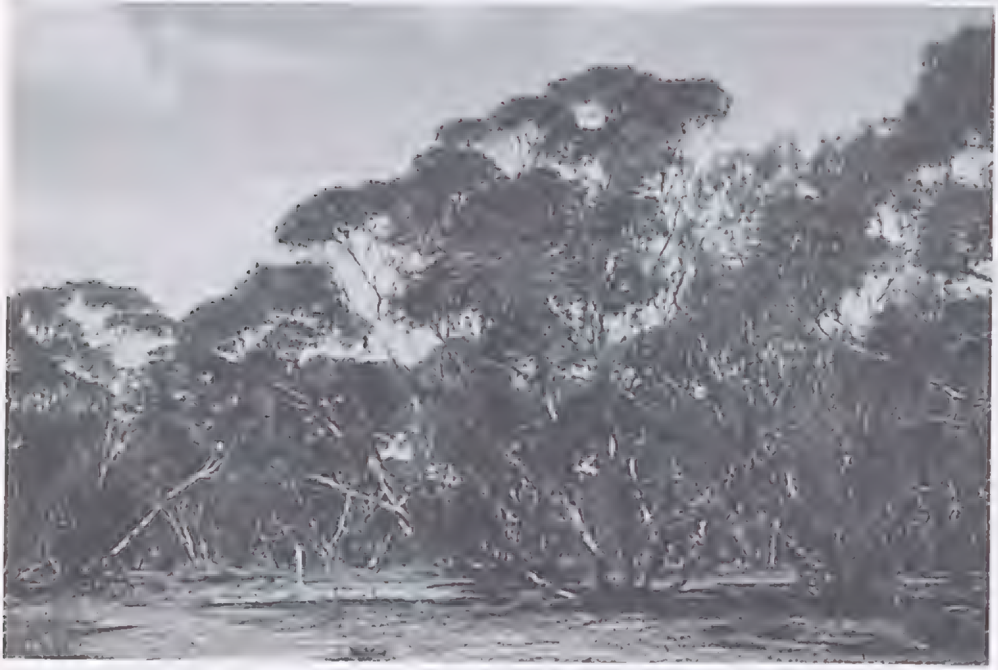

Figure 8. Sandplain Mallee along Abbots Tank - Prungle road.

those on the adjacent dune crests. This community merges with the Sandplain Mallee of 3d.

3d. Sandplain Mallee

Structure: tall shrubland *; mallee shrubland - mallee woodland **

Characteristic species: *Eucalyptus dumosa, E. oleosa,*

Associated species: *Atriplex stipitata, Zygophyllum apiculatum, Z. aurantiacum, Maireana pentatropis, Maireana pyramidata, Maireana* spp., *Enchylaena tomentosa, Sclerolaena obliquicuspis, Chenopodium curvispicatum, *Psilocaulon tenue,* often with *Dissocarpus paradoxus* and some *Eucalyptus gracilis.*

Soils: Grey-brown loam to clay-loam calcareous earths on extensive level plains often with limestone nodules on the surface (Eldridge 1985).

Occurrence: Within transition zone between aeolian and alluvial landscapes, on southern part of the Willandra Lakes system. Flat plains with no dunes. Fig. 8.

Comments: Like the Swale Mallee the trees here tend to be larger with fewer stems. The understorey is shrubby with many chenopods. The structure becomes more open as the soils become clayier nearer the transition to the riverine plain. This form of mallee overlaps somewhat with the Swale Mallee (3c).

Map unit 4: Belah-Rosewood

Structure: woodland *; open woodland - isolated clumps **

Characteristic species: *Casuarina pauper, Alectryon oleifolius* subsp. *canescens.*

Associated species: *Exocarpos aphyllus, Olearia muelleri, Myoporum platycarpum, Enchylaena tomentosa, Einadia nutans, Sclerolaena* spp., *Maireana* spp.

Geijera parviflora in the larger stands in the north.

Soils: Brown calcareous earths on plains with isolated sandy rises; deep brown and red loam to loamy sands. *Casuarina pauper* is an indicator of the presence of calcium carbonate in the lower soil horizons (Johnson pers. comm.)

Occurrence: This woodland is widespread throughout the mapped area. In the far north of the map in the mallee sand dune country it occurs in the low-lying areas of the swales where the soil is heavier. These areas were too small to map separately but due to their consistent recurring pattern were shown as a mosaic unit (mapped as 3b/4). This unit is more extensive to the north-west of the map on the Ana Branch - Mildura sheet (Fox 1991).

Larger areas of this community have been delineated, such as a band to the north-west of 'Bidura'. Much of this has been cleared for crops. This was also the case further south in the Sandplain Mallee, unit 3d, just north of the Sturt Highway. It is also associated with old lake and river systems in the north-east of the map, often seen with *Callitris* mixed woodland in undulating country.

Dotted in the south-east on heavy clay soils associated with the floodplains between the Murrumbidgee and Edward Rivers in close proximity to unit 2, *Eucalyptus largiflorens,* Belah (*Casuarina pauper*) dominates the groves, many of which are cleared or thinned. With further sampling this may be seen as a separate unit to that in the north.

Comments: This community showed the greatest variability of all those mapped. The main canopy species is Belah (*Casuarina pauper*) with varying amounts of Rosewood (*Alectryon oleifolius* subsp. *canescens*). Both species may form single-species groves, for example, in the centre-north of the mapped area to the east of the mallee, and scattered throughout the transition zone in the middle of the map, often within chenopod shrublands. They also commonly occur as a mixture forming woodlands proper, with Belah the dominant tree species, for example in Mallee Cliffs National Park and the dune country. These characteristics are also noted by Cunningham *et al.* (1981). Beadle (1948) has a separate classification for the two dominants but at this mapping scale they have been placed in the one community. *Casuarina pauper* (Belah), is referred to as *Casuarina lepidophloia* by Beadle, and later, by authors, as *Casuarina cristata* (Belah).

Map unit 8: Black Bluebush

Structure: Low - low open shrubland *; open - sparse chenopod shrubland **

8a. Characteristic species: *Maireana pyramidata*

Associated species: *Rhagodia spinescens, Enchylaena tomentosa, Atriplex* spp., *Sclerolaena* spp., *Stipa nodosa, Stipa elegantissima*, annuals.

8b. = same community as 8a but a more sparse shrubland usually on scalded areas often associated with areas along old stream beds and lunettes, or areas that have been particularly overgrazed and/or cleared.

Soils: Red-brown sand and loam duplex soils. Deep sandy soils in which limestone exists at a greater depth than 1.2 m below the surface (Beadle 1948).

Occurrence: This community occurs throughout the whole map area, most common in the transition zone between the aeolian sand-dune country and the riverine plain. It is closely associated with lunettes and source-bordering dunes of old river systems. The best stands are in the area of the north-east corner of the map through to the boundary with the mallee country to the west. However, it also occurs south-east of Balranald. It may occur as the understorey of an adjacent woodland, such as Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) (community 4) near Prungle, or of mallee such as on the Prungle Mail road. Fig. 9.

Comments: This community is the most widespread of the shrublands in the mapped area. It is found on slightly higher ground than the saltbush shrublands of *Atriplex vesicaria - Sclerostegia tenuis*, an adjacent community (11) in the far north-east of the map. It occasionally grades into Pearl Bluebush (*Maireana sedifolia*) (community 9), which occupies areas of higher elevation.

The soils are susceptible to scalding whereby the topsoil is removed by wind leaving a hard bare B-horizon surface devoid of vegetation. Scalded areas have been mapped as a subunit of this community to indicate this sparse shrub cover. Grazing pressure also reduces shrub cover and heavily disturbed areas are also included in this subunit.

Map unit 9: Pearl Bluebush

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species: *Maireana sedifolia*

Associated species: *Enchylaena tomentosa, Rhagodia spinescens, Stipa elegantissima, Maireana pyramidata.*

Soils: Red-brown sand or loam duplex soils. Deep sandy calcareous soils in which limestone exists less than 60 cm below the surface (Beadle 1948).

Occurrence: Closely associated with Black Bluebush (*Maireana pyramidata*) (community 8) usually on slightly higher ground, such as on the crest of a rise in the undulating country in the north-east sector of the map. Occasionally occurs in open areas within the mallee country such as to the north of and along the eastern boundary of Mallee Cliffs National Park. Fig. 10.

Comments: *Maireana sedifolia* is much less common than *Maireana pyramidata* and can occur as a mixed community or as a dominant in itself. Many patches are too small to include on a map at this scale. This community is more common west of the

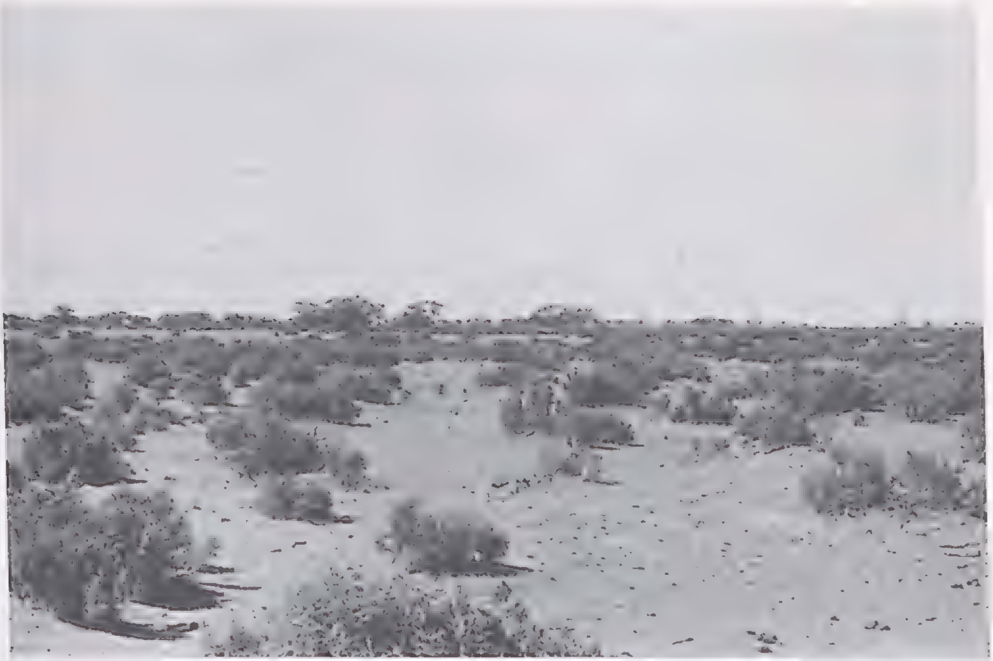

Figure 9. Black Bluebush shrubland (*Maireana pyramidata*) with very little ground cover after recent grazing.

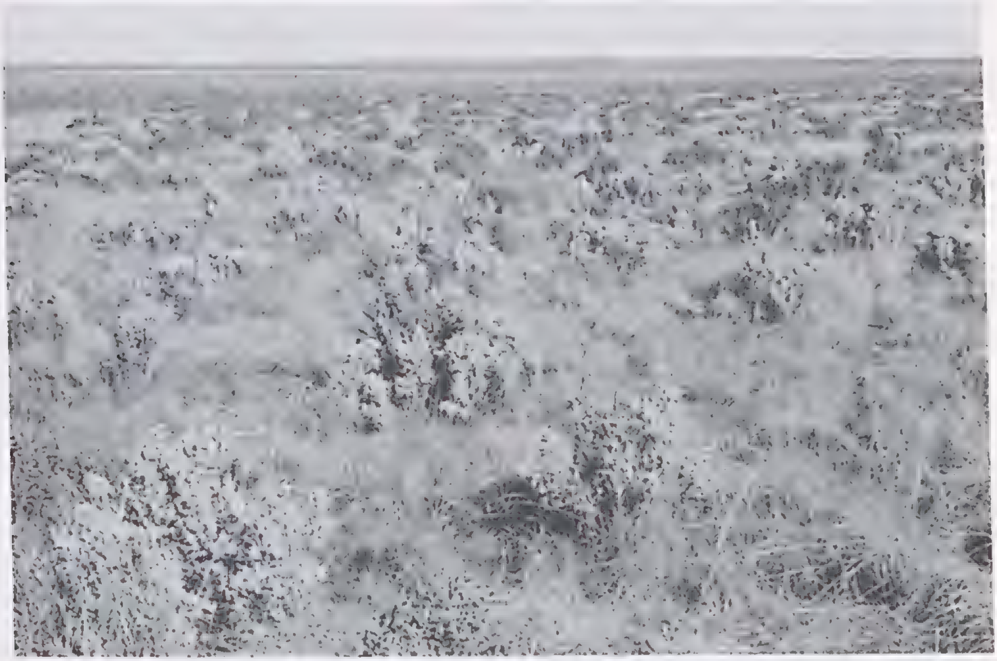

Figure 10. Pearl Bluebush (*Maireana sedifolia*) occurs on the crests of an undulating plain with Black Bluebush (*Maireana pyramidata*) downslope.

mapped area where the soil becomes more calcareous. The distribution of *Maireana sedifolia* may have been more widespread in the past, but the effects of grazing and soil changes may have seen it replaced with *Maireana pyramidata* (Beadle pers. comm.).

Map unit 11: Bladder Saltbush with *Sclerostegia tenuis*

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species: *Atriplex vesicaria, Sclerostegia tenuis.*

Associated species: *Malacocera tricornis, Disphyma clavellatum, Dissocarpus biflorus* var. *biflorus, Brachycome trachycarpa,* annuals such as *Plantago drummondii, Senecio glossanthus, Brachycome lineariloba, Rhodanthe corymbiflora, *Bromus rubens, *Lamarckia aurea.*

Soils: Red and brown or yellow-grey compact clay or clay-loam soils.

Occurrence: In the eastern half of the region, the vastest areas in the north. It is often broken by areas of *Maireana pyramidata* (community 8) and *Atriplex nummularia* (community 19).

Comments: There is considerable variation in the degree of dominance of the two main species, ranging from the dominance of one with the absence of the other to varying abundance of both. In the north-east corner of the map area there are extensive shrubland's dominated by *Sclerostegia tenuis* with small circular depressions of Canegrass, *Eragrostis australasica. Disphyma clavellatum* also occurs in this community in certain low-lying, saline areas but is not nearly as common as it is further west (Fox 1991) and it has not been mapped as a separate unit. One example of this is along the Nap Nap road on flat areas with *Atriplex vesicaria.* This community occurs in greater extent on the Riverine Plain to the east.

Map unit 13: Canegrass

Structure: grassland * & **

Characteristic species: *Eragrostis australasica*

Associated species: *Eleocharis pallens, Juncus aridicola, Juncus flavidus, Muehlenbeckia florulenta.*

Soils: Slightly saline, compact heavy grey clay soils on which water is ponded for several months (Cunningham *et al.* 1981).

Occurrence: Generally throughout the eastern half of the area in low-lying areas of swamps, table-drains and claypans within the chenopod shrublands of communities 11 and 21. Typically occurring in small depressions (each one unmappable at this scale) within *Atriplex vesicaria - Sclerostegia tenuis* shrublands (community 11) in the north-east of the map area. Areas with the highest occurrence of Canegrass depressions have been mapped as a mosaic unit 11/13. It also occurs along the old creek-line of Box Creek on the Prungle Mail road. It is seen in larger stands south-west of Perekerten and may grow with Lignum and in the riverine communities.

Comments: Areas of canegrass are subject to regular, but generally not prolonged inundation (Semple 1990).

Map unit 16: *Callitris* mixed woodland

Structure: open woodland *; open woodland - isolated trees **

Characteristic species: *Callitris glaucophylla, Hakea leucoptera , H. tephrosperma.*

Associated species: *Eremophila longifolia, Dodonaea viscosa* subsp. *angustissima, Pittosporum phillyreoides,* also at times with *Alectryon oleifolius* subsp. *canescens, Casuarina pauper* or *Allocasuarina luehmannii, Acacia melvillei, Geijera parviflora.* Near the Murray River *Callitris preissii* subsp. *murrayensis* may replace *C. glaucophylla.*

Soils: Deep coarse-textured red and brown sands and sand-loams.

Occurrence: Usually as remnants on elevated red sandy ridges occurring throughout the region, usually corresponding to old source bordering dunes of prior streams and lakes. More common in the south-east such as near Condoulpe Lake, south of Balranald, though much of this has been cleared. One of the best remnants is 2 km north-east of 'Lyle' though this would have been more extensive in the past. Raised areas of old lunette remnants on the Murrumbidgee floodplain have remnants of this community, often with *Maireana pyramidata*. These areas have been heavily grazed and much of the previous shrub cover has been removed (Pressey *et al*. 1984).

C. glaucophylla with or without associated species may occur in a mosaic with Belah-Rosewood (community 4) in the mallee dune country and the undulating country in the north to the Balranald - Ivanhoe road.

Comments: Much of this community in the south-east of the region has been cleared leaving only a few isolated individual trees or roadside patches. The understorey is often disturbed by rabbits which find this soil ideal for burrowing with its sandier texture than that of the clays of the plains further east. The only regeneration of *Callitris* was observed in roadside remnants in the Swan Hill area. The isolated trees remaining in many of the paddocks in the Swan Hill area are indicative of a greater abundance in the past. In 1836 Mitchell reported sand hills in this area 'covered with pine' (Andrews 1986). Early settlers cleared most of this community for crops and used the hard timber of the *Callitris* for fence posts and buildings.

In the south *Callitris preissii* subsp. *murrayensis* may replace *Callitris glaucophylla*. These two species readily hybridize. Only isolated trees, often in cleared paddocks or roadsides remain. This community has not been separated here for mapping purposes as its remnant nature posed a difficulty to map.

The associated species, particularly *Eremophila longifolia* and *Dodonaea viscosa* subsp. *angustissima*, are occasionally seen in the south-east of the mapped area as forming a separate shrubland on source bordering dunes. These species are known locally as woody weeds.

Map unit 17: *Acacia melvillei* woodland

Structure: tall shrubland - low woodland *; open woodland - open shrubland

Characteristic species: *Acacia melvillei*

Associated species: *Enchylaena tomentosa, Sida corrugata, Rhagodia spinescens, Nitraria billardieri*, often with **Medicago* spp., *Tetragonia tetragonioides, Goodenia fascicularis* and *Zygophyllum* spp.

Soils: Brown-red loamy calcareous earths.

Occurrence: *Acacia melvillei* may form groves as a single dominant species. The largest of these is located just to the south and the north of Balranald, where they are large enough to be mapped as a separate unit. Grazing of stock and rabbits has resulted in a sparse understorey. Some resprouting of the acacias occurs, but generally very little regeneration is to be seen at present.

Groves of smaller size occur throughout the area, less so in the mallee of the north-west. *Acacia melvillei* also appears dotted throughout the south-east of the map area, often as one or two trees, possibly remnants of once larger areas that have been cleared or grazed.

Comments: *Acacia melvillei* may have been formerly included under *Acacia homalophylla* (Yarran). These 2 species are often confused.

Map unit 18: Lignum

Structure: open scrub *; shrubland - open shrubland **

This unit was not sampled, so information has been taken from literature.

- Murray River floodplain (Margules & Partners *et al.* 1990): *Muehlenbeckia florulenta, Einadia nutans, *Bromus rubens,* with or without *Chenopodium nitrariaceum;*
- Murrumbidgee (Pressey *et al.* 1984): *Muehlenbeckia florulenta, Senecio cunninghamii, *Medicago* spp., **Phalaris paradoxa.*

Soil: Strongly gilgaied, grey self-mulching clay soils (Pressey *et al.* 1984)

Occurrence: This community generally occurs on the floodplains at a higher elevation than *Eucalyptus camaldulensis* around the fringes of grey-soil open country (Pressey *et al.* 1984). It is most abundant in the Lowbidgee Area, under River Red Gum, (*Eucalyptus camaldulensis*) and Black Box, (*Eucalyptus largiflorens*) or as vast areas of monospecific stands. On the road to 'Yanga' station much of the Lignum has been cleared for cropping.

Comments: *Muehlenbeckia florulenta* (previously *Muehlenbeckia cunninghamii*) generally occupies areas that experience relatively infrequent (e.g. once in 3 years) but often prolonged flooding (Semple 1990).

Map unit 19: Old Man Saltbush

Structure: low shrubland *; open-sparse chenopod shrubland **

Characteristic species: *Atriplex nummularia*

Associated species: *Atriplex vesicaria, Rhagodia spinescens, Atriplex* spp., *Sclerolaena* spp.

Soils: Mostly on grey and brown clay soils, usually in flat or low-lying situations. Can be found on practically all soils and at all levels (Cunningham *et al.* 1981).

Occurrence: Throughout the mapped area except the mallee, in a range of situations. Most often on grey clay soils near *Eucalyptus largiflorens* woodlands and along drainage lines. The largest areas are just north of Yanga Nature Reserve and south of Waldaira Lake. The community also occurs on red-brown earths in other chenopod shrublands such as communities 8, Black Bluebush and 11, Bladder Saltbush with *Sclerostegia*, throughout the north-east sector of the map, for example on the Ivanhoe road north of Box Creek and along the old drainage line of Box Creek following Prungle Mail road, though separate populations are too small to map. Fig. 11.

Comments: The current distribution within these communities ranges from small clumps to scattered isolated individuals. This community had a much greater distribution on the Riverine Plain in the past, but has diminished as a result of grazing (Beadle 1948). It is deep rooted and a palatable species to stock (Cunningham *et al.* 1981).

Map unit 20: Bull Oak

Structure: open woodland *; isolated plants - isolated clumps **

Characteristic species: *Allocasuarina luehmannii*

Soils: Deep brown and red sands and sand-loam.

Occurrence: This community is found on sandy rises in the south-east of the map. Usually it is seen as a few single trees, rarely in groves as in *Casuarina pauper* and usually in association with *Callitris preissii* subsp. *murrayensis.* It is more frequent further east and thought to have originally occurred in association with *Callitris* which have been removed for fencing and building purposes (Cunningham *et al.* 1981). An example in the mapped area is near 'Lyle', south-east of Balranald, in the area of mixed *Callitris* woodland mentioned in the description for community 16. Isolated trees are found on the corner of the Swan Hill and Moulamein roads south of Balranald. Also present here is Wilga (*Geijera parviflora*), *Acacia oswaldii* and *Callitris preissii* subsp. *murrayensis* and mallee nearby. This community was not extensive enough to be mapped as a separate unit.

Map unit 21: Cottonbush

Structure: low shrubland *; open-sparse chenopod shrubland **

Characteristic species: *Maireana aphylla*

Associated species: *Atriplex vesicaria*, *Atriplex leptocarpa*, *Nitraria billardieri*, *Sclerolaena* spp. and annual species *Calocephalus sonderi*, *Rhodanthe stuartiana*, **Cotula bipinnata*.

Soils: Yellow-grey and grey clay soils.

Occurrence: Restricted to the south-eastern corner of the map area on flat plain country south of the Murrumbidgee River. For example along the Keri Keri road.

Comments: This community is typical of the Riverine Plain to the east. Commonly in association with *Atriplex vesicaria*, it occupies areas of flat plain, marking the westernmost edge of the Riverine Plain. The patches are discontinuous (unlike the community on the plain further east), broken up by the other landforms and associated vegetation types of this transition zone between the plain and the mallee. Many of the associated species are indicative of disturbance from grazing, the main land-use of this area.

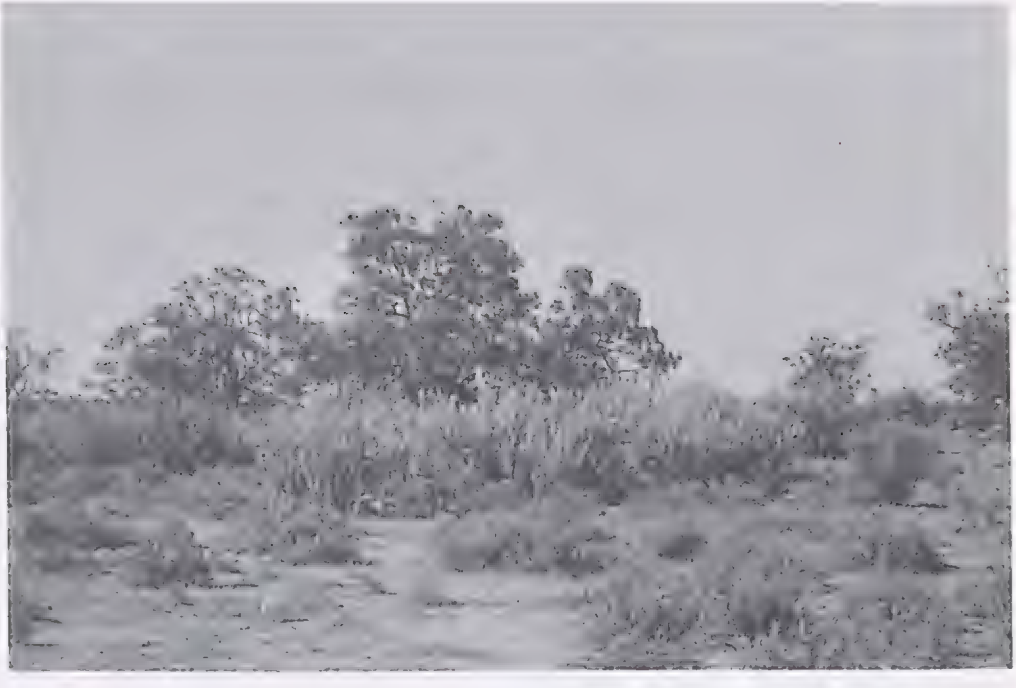

Figure 11. Old Man Saltbush (*Atriplex nummularia*) in an area of restricted drainage, with Black Box (*Eucalyptus largiflorens*) in the background.

Map unit 22: Dillon Bush

Structure: low - low open shrubland *; sparse shrubland **

Characteristic species: *Nitraria billardieri*

This community usually occupies a disturbed area and can occur within most communities as a result of overgrazing or clearing. Associated species vary depending on the original vegetation. Usually there is a high percentage of grasses, weeds and annuals with the occasional shrub for example, *Einadia nutans, Sclerolaena spp.* and *Atriplex spp.* Annual grasses and Asteraceae commonly occur. *Nitraria billardieri* may be present only as an occasional shrub. Before European settlement, *Nitraria billardieri* probably occurred in very small quantities in the shrubland communities (Beadle 1948). Since then, the occurrence of this species has increased with the subsequent changes in landuse (Beadle pers. comm.).

Soils: usually clay and loam soils, often saline areas. In the Lowbidgee the soils are strongly gilgaied grey self-mulching clays (Pressey *et al.* 1984).

Occurrence: On plains and floodplains throughout the region, predominantly in the east, such as dry lakebeds that have been grazed or left after cropping, overgrazed areas, and previously cropped areas.

Map unit 23: Great Cumbung Swamp

This unit was not sampled and is taken from Pressey *et al.* (1984).

Structure: closed - open herbland *; closed - open grassland/forbland **

Characteristic species: *Phragmites australis, Senecio cunninghamii*

Associated species: *Paspalum distichum, *Cirsium vulgare, Pratia concolor*, often with **Hordeum leporinum*, and **Polypogon monspeliensis.*

Within this unit *Senecio cunninghamii* occurs on the higher ground on the edge of the swamp, with *Phragmites australis* in the swales and down to the upper limit of *Typha orientalis* which grows in the water.

Soils: Heavy clay soils.

Occurrence: In the Great Cumbung swamp at the far eastern edge of the map.

Map unit OA: Open Areas

'OA' indicates 'open areas' occurring mostly on the aeolian soils of the mallee country. They are thought to be naturally occurring areas of heavier soil (Eldridge pers. comm.) supporting shrubs, herbs and grasses. Within the Sandplain Mallee many of the 'open areas' follow old drainage lines. Within Mallee Cliffs National Park, Morcom and Westbrooke (1990) referred to these areas as 'herbland - open herbland' resulting from the modification of chenopod shrublands or arid woodlands caused by grazing pressure.

Some of the less disturbed open areas to the north of and on the eastern boundary of Mallee Cliffs National Park support Pearl Bluebush (*Maireana sedifolia*) shrubland (community 9). Close to tanks, stocking pressure may have reduced many of these areas to predominantly grasslands. South of Mallee Cliffs National Park the open areas occasionally have patches of Belah (*Casuarina pauper*). Some areas of mallee cleared for grazing in the earlier years may have partially regrown where lignotubers have not been completely removed (Fitzpatrick 1982) creating areas of open mallee.

Open areas in the mallee west of Euston are a result of frequent prescribed burning. Three fires in the space of seven years have led to a depletion of mallee in the swales creating open grasslands (Noble 1984). Common species include *Sclerolaena obliquicuspis, Stipa nitida, Stipa nodosa*, often with *Dissocarpus paradoxa, Salsola kali*, and **Silene apetala.*

Discussion

Distribution of plant communities

The major cause of variation in vegetation in semi-arid south-eastern Australia is the interaction between soil texture and rainfall (Noy-Meir 1974, Beadle 1948). Within the mapped area the distribution of the vegetation communities also strongly reflects landform.

Aeolian landscape

Mallee dominates the aeolian sandsheet that stretches across South Australia, northern Victoria and south-western New South Wales. Within this map sheet differences in species composition and structure resulted in the four broad mallee communities described. The various mallee communities mapped overlap and grade into each other. The map attempts to reflect the major trends. A high variability of species composition was observed in the mallee which would only be objectively delineated with extensive sampling.

Dune Mallee predominates in the west and north of the map, but varies from north to south. In the north the dune-crests are dominated by Dune-Crest Mallee (3b) with species such as *Triodia scariosa*, *Eucalyptus costata* and *Callitris verrucosa* restricted to the deep sands. The swales, where the soils are heavier and have a greater clay content, support Belah-Rosewood (*Casuarina pauper* - *Alectryon oleifolius* subsp. *canescens*) (community 4). It was not feasible at this scale to map the individual clumps of Belah-Rosewood in the swales. For mapping purposes these two communities have been combined as a mosaic unit due to the consistent recurring pattern. This pattern is more extensive to the west and north of this map. This unit mapped is equivalent to unit 5 in Fox (1991).

In the south this pattern changes with swales comprising mallee (3c) with a chenopod dominated understorey. There is an occasional Belah-Rosewood (*Casuarina pauper* - *Alectryon oleifolius* subsp. *canescens*) patch but these are isolated and do not follow the pattern observed further north. Larger patches of Belah-Rosewood appear in the Sandplain Mallee in the centre of the region, though many of these have been cleared.

The sandplains are devoid of dunes and have heavier soils with a greater water-holding capacity. There is a dominance of chenopods in the understorey and the trees are often larger and with fewer stems. They are structually referred to as 'bull mallee' as opposed to 'whipstick mallee' typical of the dune crests (Beadle 1948). In western NSW these growth forms are thought to be a result of differences in soil type (Beadle 1948) or more recently, of fire occurrence (Noble 1982). *Triodia scariosa* on the dune crests is more flammable than the shrubs in the understorey of the swales and sandplains. When 'bull' mallee is burnt, often after the buildup of *Stipa* spp. in the understorey, it regenerates first as a 'whipstick' form but eventually regains its 'bull' mallee form (Noble 1982). Fire in the mallee can also create differences in floristic composition at different stages of regeneration (Brickhill 1988, Noble 1989). Within the mapped area the last major fires were in 1974-75, but there were experimental fires just west of Euston in 1980 and 1982 (Noble 1984). Open treeless areas within the mallee are flats of hard pedal red duplex soils (Walker 1991) supporting grasses and herbs. Many such areas have been caused by frequent fires (Noble 1984).

The Sandplain Mallee community correlates closely with the soil-landform association type 'O1' of Eldridge (1985). This form of mallee is similar to the 'chenopod mallee' of the Sunset country in Victoria (Land Conservation Council 1987).

A larger percentage of Sandplain Mallee has been cleared than of the other mallee types. The topography is flatter, the soil is heavier and less susceptible to erosion as well as being easier to clear.

Of higher preference for clearing is Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) woodland. This community occurs on the lower flatter areas within the aeolian country in the west, and on the undulating country in the transition between the aeolian landform to the riverine plain in the east. It is far more extensive to the north and north-west of the mapped area (Fox 1991, Beadle 1948). This community shows the greatest variability of all the communities mapped. Structurally it forms woodlands covering fairly large areas such as on the northern boundary of Mallee Cliffs National Park, or isolated clumps in chenopod shrublands as on the undulating country bordering the riverine plain. Floristically it commonly consists of a mixture of the two tree species, or single-species stands of either species often appearing in groves.

Often associated with the Belah-Rosewood woodlands is Black Bluebush (*Maireana pyramidata*) shrubland (community 8). This community is the most widespread of the shrublands in the mapped area. It occurs most commonly on the undulating country marking the transition from the riverine plain in the east to the aeolian sand dunes to the west. It is closely associated with lunettes and source-bordering dunes of old river systems. The soils have a lower clay content on these elevated areas than on the riverine plain. Pearl Bluebush (*Maireana sedifolia*) (community 9) is less common but also found on this landform, often mixed with and/or on slightly higher elevated land than community 8. Extensive areas of this community occur west of the mapped area and into South Australia where the soil becomes more calcareous (Scriven 1988b, Dalton 1988).

Fluvial landform

The vegetation on the eastern edge of the map sheet begins to reflect the Riverine Plain vegetation. Communities extensive on the grey-brown clays further east occur as discontinuous patches in the transition zone between the plain and the mallee. Bladder Saltbush (*Atriplex vesicaria*) with *Sclerostegia tenuis* (community 11) occurs throughout this zone but is more extensive in the north in association with Canegrass (*Eragrostis australis*) depressions. South of the Murrumbidgee River, Cotton Bush (*Maireana aphylla*) (community 21), commonly in association with *Atriplex vesicaria* occupies flat plain areas of grey clay soils. Many of the species in this community are indicative of disturbance from grazing. This trend in the shrubland communities continues further east onto the Hay Plain.

The landforms associated with the prior stream traces which cut across the Hay Plain continue into the south-east of the mapped area. The old raised stream beds and source-bordering dunes support remnant *Callitris* Mixed Woodland (community 16) and Black Bluebush (*Maireana pyramidata*) (community 8). Extensive clearing of *Callitris* has had the result that only remnants of this community remain. These remnants are highly threatened also by the grazing of stock and goats, and the destructive burrowing of rabbits, which prefer the sandier soil of this habitat to the clays of the Riverine Plain.

The only 'forest' type vegetation on the map sheet is Riverine Forest (community 1) dominated by *Eucalyptus camaldulensis* (River Red Gum). This community continues along the length of the inland rivers from NSW into South Australia, differing along its length in its associated species (Margules & Partners *et al.* 1990). Closely associated is Black Box woodland (*Eucalyptus largiflorens*) (community 2), also continuing to the east and the west, and patches of Lignum (*Muehlenbeckia florulenta*) (community 18). A comprehensive study of the Murray River system has been prepared by Margules & Partners *et al.* (1990) for the Murray Darling Basin Commission giving greater detail of the vegetation than presented here.

Old Man Saltbush (*Atriplex nummularia*) (community 19) may grow on many soil types (Cunningham *et al.* 1981) but is found in greatest numbers on the floodplains and the loamier soils of the undulating country of the 'transition zone'.

Species composition and variability of the vegetation

A total of 81 families of plants were represented in the mapped area, the main ones being Chenopodiaceae, Asteraceae and Poaceae. These families contain a large number of annual and short-lived perennial species.

A major drawback with this form of mapping in the semi-arid region is the lack of sampling throughout the year and from year to year. Similarity of plant community composition between sequential seasons in south-western New South Wales is very low, commonly 55–70%, with the turnover of the ephemeral component of the understorey very great (Fox 1990). Fox (1990) has found both the number and particular combination of species is a function of the seasonal rainfall. This mapping project has largely based the community descriptions on perennial species. Many of the annual grasses and herbs were not specific to a particular shrubland community, but are very widespread. Common annual and short-lived perennial species are the grasses **Hordeum leporinum*, **Bromus rubens*, *Danthonia caespitosa*, *Stipa* spp.; and forbs such as *Rhodanthe* spp., *Brachycome lineariloba*, **Sonchus oleraceus*, *Senecio glossanthus*, *Vittadinia* spp., (Asteraceae); *Atriplex lindleyi*, *Atriplex pseudocampanulata*, *Sclerolaena brachyptera*, *S. muricata*, *S. diacantha* (Chenopodiaceae); and a number from other families such as **Medicago* spp. (Fabaceae). A large component of the annual flora are introduced species.

Landuse and changes to native vegetation

The vegetation of the mapped area has been altered since the European settlers came to the area 160 years ago. The degree of disturbance increases generally from the north to the south of the mapped area, that is, along a gradient of water availability and better soils. The following impacts on the native vegetation were observed, but not investigated, in the course of this study.

Grazing effects

The grazing of sheep on native pastures is the main land use of the region (Semple 1989). Some cattle grazing occurs on the eastern edge of the mapped area. Grazing of the Riverine Plain in the east has occurred since 1830. By the 1840s there were reports that grazing had led to the reduction of the proportion and the regional distribution of saltbushes (*Atriplex* spp. and *Sclerolaena* spp.) replacing them with grasses (Williams 1962 & Buxton 1967 cited in Butler *et al*, 1973). Scriven (1988*b*) outlines the effects of grazing as reflected in the change in composition and biomass of the vegetation, and the compaction and erosion of the soils. Areas of Dillon Bush (*Nitraria billardieri*) (community 22) are indicative of disturbance from grazing and clearing.

The mallee country was less suitable for grazing because of its low productivity, inaccessibility and lack of reliable water supplies. However, grazing occurs throughout the mallee and in Mallee Cliffs National Park high levels of weediness can be directly linked with previous grazing history (Westbrooke 1990).

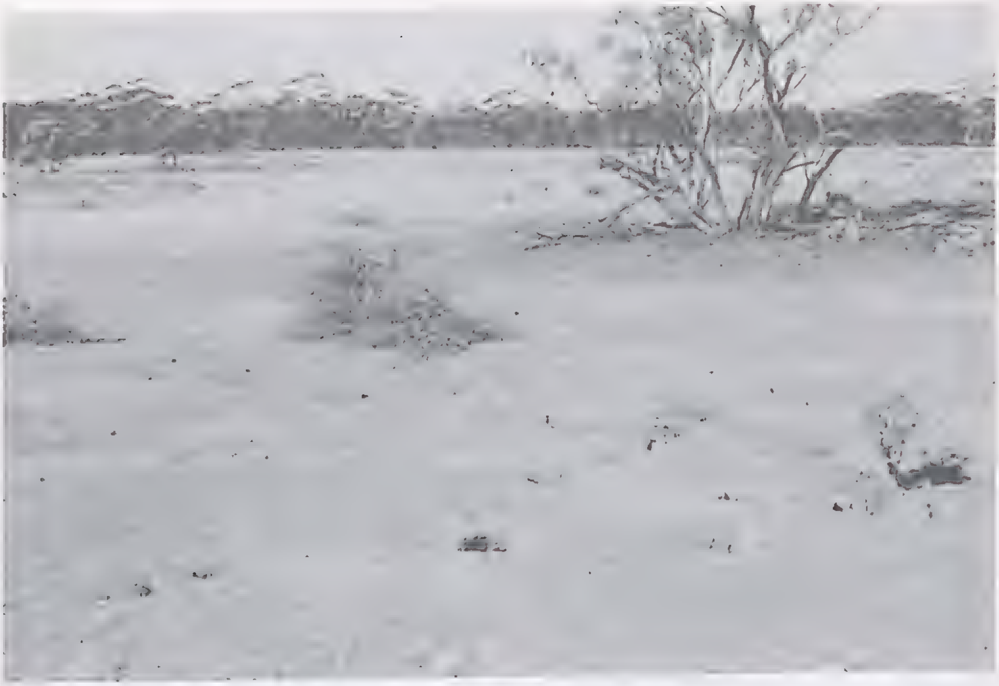

Figure 12. Disturbance by rabbits is a problem in areas with sand and loam soils, such as this area of cleared mallee.

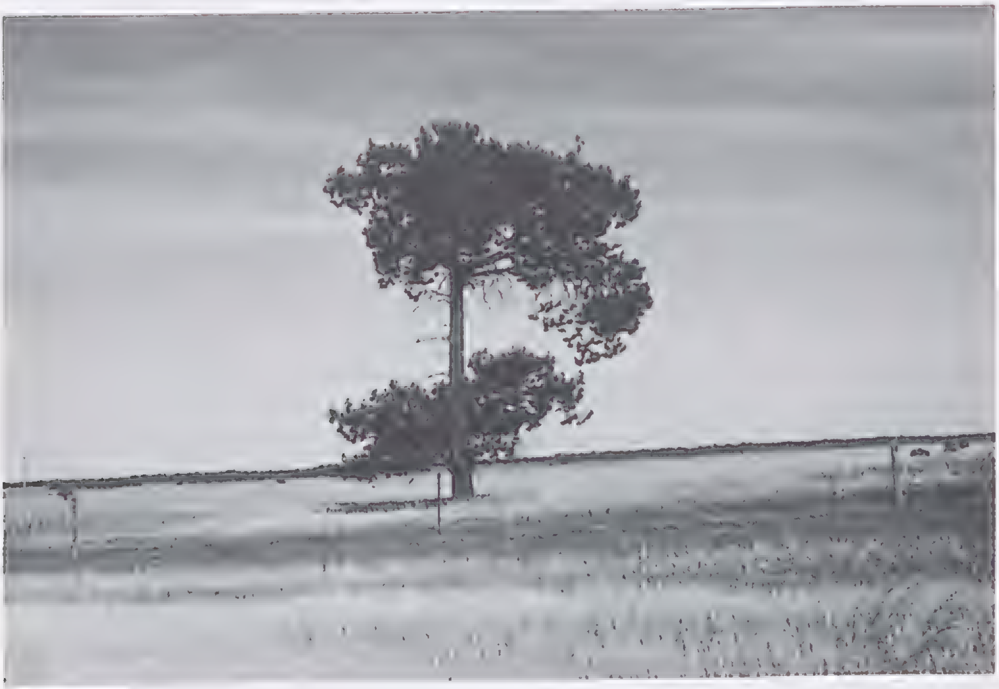

Figure 13. *Callitris* woodland has been extensively cleared for cropping and for the use of its timber. In the south, often a lone tree in a cleared paddock is indicative of its once greater abundance.

Rabbits and goats compete with sheep and native fauna for forage. This places added pressure on the native vegetation. Continual grazing changes the original herbaceous ground layer of predominantly perennial native plants to predominantly annual species with a high percentage of introduced weeds (Land Conservation Council Victoria 1987, Calder 1990). Large areas of Belah (*Casuarina pauper*) and *Callitris* woodland and 'savannah mallee' in Victoria have been so degraded from grazing that the original community is being destroyed and replaced by annual herblands and grasslands (Land Conservation Council Victoria 1987).

Lack of regeneration, particularly in the woodland communities, seen in the course of this work and by other authors (Wilson *et al*. 1976, Chesterfield and Parsons 1985) is a serious problem that needs immediate attention. Fig. 12.

Clearing and Cropping

The Weimby-Kyalite area south-west of Balranald, and the Benanee area to the north-east of Euston are major dryland cropping areas in the Western Division. They are regarded as marginal cropping areas because of the low and erratic rainfall (Eldridge & Semple 1982). The greatest clearing has occurred very recently, with a ten-fold increase in dryland cropping in the Western Division since the mid-1960s (Pressey 1990).

This agricultural use started with small-scale cropping for horse feed and was replaced by commercial cropping on soldier settlements in the 1920s (Mabbutt & Williamson 1982). Over-clearing and over-cultivation in the Benanee area caused serious soil erosion in the early years (Alchin 1980).

The original vegetation for this area was mallee and Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) woodland growing on calcareous sands and earths and red and yellow duplex soils. The woodland was preferentially cleared because of its more suitable soil type for cropping and the greater ease of clearing than the mallee with its large lignotubers (Stanley & Lawrie 1980). Dryland cropping has also occurred in the old lake beds around Balranald, where the previous vegetation was probably chenopod shrublands or grasslands. The principal crops are wheat, barley and other cereals.

Adverse effects of land clearing in this landscape have been outlined by authors Melville, Mabbutt, Williamson and Dodson in Mabbutt (1982), Leys (1990) and Pressey (1990*c*). They include a decline in the abundance and diversity of species, fragmentation and reduction in the area of some natural environments, and changes in the water balance of the soils that lead to soil erosion and invasion of noxious weeds.

Clearing is more extensive in the Central Division of NSW., which consists of freehold land, where there are less restrictions. Clearing in the Swan Hill area has left very little remaining natural vegetation. Only remnant trees in paddocks and on roadsides remain of the previously extensive *Callitris* woodlands (Andrews 1986). Black Box (*Eucalyptus largiflorens*) would also have covered much of the floodplain here. Fig. 13.

The Lowbidgee District to the east of Balranald and south of the Murrumbidgee River, has the most agriculturally productive land due to its fertile alluvial soil and water supply (Department of Water Resources 1991). Grazing is the dominant land-use, supplemented by the growing of agricultural crops. This area has the best stands of Lignum (*Muehlenbeckia florulenta*) in NSW (Department of Water Resources 1991). Landholders use the Lignum for grazing stock and 40% has been cleared for cropping.

In the immediate surroundings of the towns of Balranald, Euston and Swan Hill, and along the Murray River, irrigation is used for crops of predominantly grapes and citrus. The native vegetation affected in these areas would most probably have been Black Box (*Eucalyptus largiflorens*) woodlands, on the grey clay soils of the floodplain, and *Callitris* Mixed Woodland, on the sandier rises.

Fire

Fire has been used by landholders to clear mallee land, manage native pastures for maximum grazing production, and protect life and property by fuel reduction. Prescribed burning, however, is out of phase with the natural wildfires which occur in semi-arid lands every 10–15 years or longer (McArthur 1972). The last major wildfire in the area was in 1975. Prior to European settlement, however, Aboriginal burning practices would have influenced the vegetation over a long period of time. In western New South Wales generally, Aborigines used fire for food-gathering and hunting (Mullins *et al.* 1982).

The mallee communities are the most fire-prone due to the presence of a flammable canopy and grassy understorey. The buildup of speargrass (*Stipa* spp.) in the swales following good seasonal rains produces abundant fuel for fires (Noble 1984). Noble has shown, in an area west of Euston, that two or three fire events in quick succession can markedly reduce mallee densities creating open areas. Gill (1990) and Ludwig *et al.* (1990) recommend predictive modelling and monitoring of mallee vegetation and fire events to ensure species conservation.

Salinity

Salinity has been a part of the semi-arid landscape since Pleistocene time (Macumber 1990). Land use changes over the last one hundred years however, has led to a rise in salinisation. River salinity of the Murray is outlined in Margules & Partners *et al.* (1990). Dryland salinity results from a rise in the water table bringing dissolved salts to the surface. It is caused by the clearing of trees which no longer remove the water from the soil, increasing the recharge rate to the water table. Clearing and farming practices used over the last fifty years in the Balranald area have resulted in an approximate 100-fold increase in recharge to ground water (Budd *et al.* 1990*a*). The sandier soils of the mallee have higher recharge rates than the soils with a higher clay content (Budd *et al.* 1990*b*).

Salinisation has been observed at two sites near Balranald and may be contributing to poor crop yields on dry lake beds (Eldridge & Semple 1982). The land-use and prevailing climate will determine the rate of increase and future extent of salinisation (Macumber 1990). The management of soil salinity across south-east Australia is discussed in Humphreys *et al.* (1990). Retention of native vegetation, particularly mallee on the highly susceptible light-textured soils, will reduce future salinisation problems.

Feral animals

Cooke (1990) outlines the damage in mallee lands caused by rabbits, goats, foxes, cats, hares, house mice and feral pigs. The effect of grazing in the riverine communities is reviewed by Margules & Partners *et al.* (1990). Besides sheep, the two introduced animals that have greatest impact on the native vegetation are rabbits and goats. Evidence of rabbits are most apparent in the 'transition zone' between the plain and the aeolian landscape. They also prefer calcareous red earths (Parer & Libke 1985) for burrowing, leading to erosion and damage to plant roots. They destroy the vegetation by grazing and ringbarking. Poison baits and ripping of warrens is the present method of rabbit control, since myxomatosis appears to be becoming less effective. Different means of future biological control may be a long-term means of controlling rabbit numbers.

Goats are found in greatest numbers in the aeolian sand country in mallee shrublands and Belah-Rosewood (*Casuarina pauper* - *Alectryon oleifolius* subsp. *canescens*) and *Callitris* woodlands. Their grazing of native vegetation may lead to changes in the composition of the tree and shrub components in some woodland communities (Wilson *et al.* 1976). Whilst sheep prefer short herbs, goats are more selective in their feeding and may pull down branches and climb into bushes (Downing and Mitchell 1988).

Erosion

Wind erosion leads to the removal of nutrients, the reduction of water-holding capacity on sandy soils, and exposure of the hard clay subsoils of the duplex soils (Land Conservation Council 1987, Soil Conservation Service 1989). Where the exposed clay subsoils are saline, they are referred to as *scalds*. This is the most obvious form of erosion within the mapped area, associated with old stream traces and lake systems, for example in the system to the north-west of Morvan Tank in the north-east corner of the mapped area. Scalding was noted throughout the area in the 1940s by Beadle (1948). The process of scalding is accelerated by the removal of protective vegetation by overgrazing, clearing and inappropriate cropping practices (Margules & Partners *et al.* 1990). Methods for rehabilitation of eroded areas are outlined in Scriven (1988b). As with the salinity problem, retention of native vegetation will reduce erosion. Fig. 14.

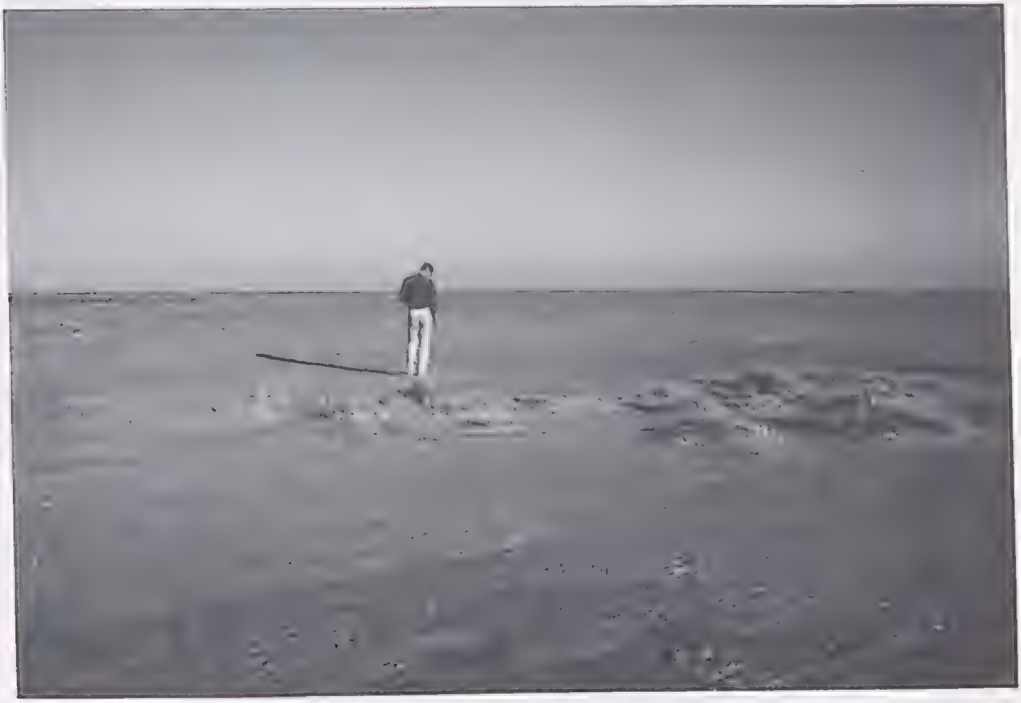

Figure 14. Overgrazing, clearing and inappropriate cropping practices may lead to vast areas of scalding.

Introduced Plants

The spread of weeds is largely associated with cropping (Eldridge and Semple 1982) and grazing (Margules & Partners *et al*. 1990, Wilson & Harrington 1984). Introduced plants seen to be particularly abundant are annuals such as **Hordeum leporinum*, **Bromus* spp., **Brassica tournefortii*, **Medicago* spp., **Sisymbrium irio*, **Sonchus oleraceus*, **Malva parviflora*. The perennial **Marrubium vulgare* (Horehound) is common along roadsides. These are replacing native perennial grasses and forbs. In all, 19% of species recorded for the mapped area are introduced. The native shrub *Nitraria billarieri* (Dillon Bush) has also colonized disturbed shrubland areas.

Conservation of the vegetation

Reserves

There are only two conservation reserves in the mapped area, and these cover only about 3% of the area.

Yanga Nature Reserve, gazetted in 1972, is located approximately 25 km by road east of Balranald. It consists of 1772 ha, mostly of Black Box (*Eucalyptus largiflorens*) woodland (community 2) with a few open areas of grasses and herbs. On a few of the raised areas are the remains of mud ovens from Aboriginal occupation of the area. These important archaeological sites are threatened by the impact of rabbits burrowing and breaking up the earthen mounds.

Mallee Cliffs National Park, gazetted in 1977, is located approximately 35 km north of Euston. Approximately 90% of the 57 969 ha is located in the mapped area, the remainder is on the adjacent Mildura map sheet to the west. The dominant plant community is mallee with areas of Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) woodland. This area contributes to the 2814 sq km or 6% of the mallee land systems conserved in the Western Division of NSW (Pressey *et al*. 1989). Rabbits and goats are a problem in the Park.

The southern-most part of the Willandra Lakes World Heritage Region occurs in the mapped area. It is a system of now dry lakes fed by Willandra Billabong Creek, a former distributary of the Lachlan River. It was declared a World Heritage area due to its outstanding cultural values (Australian Heritage Commission 1980). The lakes on the properties of 'Prungle', 'Benenong', 'Gulthul', 'Koolaman' and 'Banoon' are within the mapped area. Grazing continues in these areas under lease conditions administered by the Western Lands Commission. Mungo National Park, to the north of the mapped area, covers a part of the World Heritage area.

Conservation of vegetation communities

Benson (1989) lists the conservation status of most of the major plant communities in western New South Wales as poor or very poor, noting that the greatest impacts of European settlement have been from clearing and grazing, leading to a reduction in abundance and composition of the understorey. Within the mapped area most of the plant communities are not represented in reserves.

In the semi-arid region conservation studies have recently focussed on the mallee (Noble *et al*. 1990; Groves & Parsons 1989; Pressey *et al*. 1990*a*; Brickhill 1988; Urwin 1981). As a result some large areas of mallee such as Nombinnie Nature Reserve to the north of the mapped area, have been recently conserved.

Within the mapped area Irregular Dune Mallee (3a), Dune-Crest Mallee (3b) and Swale Mallee (3c) are represented in Mallee Cliffs National Park. Sandplain Mallee (3d) has limited representation on the eastern edge of the Park. It is the main mallee community licenced for clearing. Of this community ('chenopod mallee') 180 km^2 has been conserved in Victoria (Land Conservation Council 1987). This is 11% of the total for that state (Pressey *et al.* 1990a).

Belah-Rosewood (*Casuarina pauper - Alectryon oleifolius* subsp. *canescens*) (community 4), is also conserved in Mallee Cliffs National Park but occurs as a dominant over only 13% of the Park (Morcom & Westbrooke 1990). It is not conserved in the undulating transition zone or on the floodplain south-east of Balranald, where it occurs on the Condoulpe land system (Walker 1991). Cropping is widespread in areas occupied by this community. It also suffers from a severe reduction of understorey structure and lack of regeneration of the dominant species. Studies of the regeneration of these species have shown that grazing pressure is the major cause of decline in the populations (Chesterfield & Parsons 1985). Feral goats browse Belah and Rosewood and may change the tree and shrub component of this community (Wilson *et al.* 1976).

The *Callitris* Mixed Woodland (community 16), is one of the most threatened communities in the mapped area. It has been heavily cleared in the past and little regeneration is occurring. It is particularly vulnerable along the Murray River where *Callitris preissii* subsp. *murrayensis* occurs. Only remnants remain, often consisting of roadside trees with the understorey removed or heavily disturbed by rabbits. Most trees observed were very old and often visibly senescent. Very little recruitment is occurring.

Similarly, Bull Oak (*Allocasuarina luehmannii*) (community 20) in the south-east of the region is in poor condition. This, together with *Callitris preissii* subsp. *murrayensis*, is one of the most threatened communities in the mallee region of Victoria (Blakers & Macmillan 1988). They report that widespread degradation has resulted from grazing and weed invasion with all the best remaining areas, comprising less than 1% of the original cover, classed as 'disturbed'.

Likewise, there are no reserves conserving the riverine vegetation within the mapped area. Kemendok Nature Reserve (1 043 ha) is just west of the mapped area and is the only reserve along the Murray River in New South Wales that conserves Riverine Forest dominated by *Eucalyptus camaldulensis* (River Red Gum) (community 1). Margules and Partners *et al.* (1990) noted a general poor condition of the vegetation along the Murray River resulting from clearing, grazing, river regulation and soil salinisation.

Acacia melvillei shrubland is not conserved in any reserve system. Benson (1989) lists the inland *Acacia* and *Casuarina* shrublands/woodlands as one of the groups with the poorest conservation status in New South Wales. The scattered nature of the groves and individual plants of this species do not lend themselves easily to reserve protection. Retention of this community through altered management practices by individual property managers may be an answer to the its future survival.

Benson (1989) lists all chenopod shrublands as poorly conserved. Grazing has an impact on all the communities. None of the shrublands are conserved within the mapped area. The most threatened is Old Man Saltbush (*Atriplex nummularia*) (community 19) which has declined since European settlement. Similarly, no areas of Bladder Saltbush (*Atriplex vesicaria*) with *Sclerostegia tenuis* (community 11), Cottonbush (*Maireana aphylla*) (community 21), or Canegrass (*Eragrostis australasica*) (community 13) are reserved in the mapped area, or on the riverine plain to the east where they are more extensive.

Table 3. Species of particular conservation significance within the Balranald – Swan Hill 1:250 000 map sheet area. (a) = species nationally listed as rare or threatened (Briggs & Leigh 1988). (b) = species with restricted distributions in the Western Division of NSW (Pressey *et al.* 1990*b*).

(a)

Taxa	**Risk Code**	**Habitat**
ASTERACEAE		
Brachycome papillosa	3V	On saltbush plains on grey clay soil.
BRASSICACEAE		
Lepidium monoplocoides	3ECi	Woodlands near the Murray & Murrumbidgee River junction.
CALLITRICHACEAE		
Callitriche cyclocarpa	3V	Aquatic herb on Murray-Wakool floodplain.
SOLANACEAE		
Solanum karsensis	3RCa	On river floodplains & flooded depressions or lakebed, or disturbed area in mallee.
POACEAE		
Stipa metatoris	3V	On sandy rises with *Callitris* Mixed Woodland & mallee on red-brown sandy-loam.
Stipa wakoolica	2K	Floodplain on grey sandy-loam to clay-loam.

(b)

Taxa	**Category/ priority**	**Habitat**
ASTERACEAE		
Podotheca angustifolia	3B/4	In mallee on deep red sand.
Rhodanthe tietkensii	3B/4	In mallee on sandy soils.
Senecio murrayanus	3B/4	In woodlands.
BRASSICACEAE		
Pachymitus cardaminoides	3B/4	An ephemeral species on sandy soils.
CHENOPODIACEAE		
Sclerolaena limbata	3B/4	Heavy slightly saline soils.

FABACEAE		
Swainsona murrayana	3A/2	Grey & brown heavy clay & clay-loam soils in shrublands, Black Box & grassland communities.
Templetonia sulcata	3B/4	In mallee on sandy red earths.
MALVACEAE		
Lawrencia squamata	3B/4	In shrublands of *Maireana sedifolia*.
MYRTACEAE		
Eucalyptus porosa	3B/4	In mallee on sandy-loam soils.
POLYGONACEAE		
Muehlenbeckia diclina	3B/4	In mallee.
RUBIACEAE		
Opercularia turpis	3B/4	In mallee in the Balranald-Euston area.
SANTALACEAE		
Exocarpos sparteus	3B,4A/4	In mallee near Euston.
Santalum murrayanum	3B/4	In mallee near Euston.
THYMELAEACEAE		
Pimelea simplex subsp. *continua*	3B/4	On heavy-textured soils or sometimes in red sand.
ZYGOPHYLLACEAE		
Zygophyllum angustifolium	not yet allocated	On calcareous red & brown soils in mallee or chenopod shrublands.
CYPERACEAE		
Gahnia lanigera	3B/4	In mallee.

Risk Codes in Briggs & Leigh (1988). **2** Maximun geographic range of 100 km. **3** Range over 100 km but restricted to highly specific habitats. **E** Endangered species at risk with one or two decades under present land use. **V** Vulnerable species at risk over a longer period. **R** Rare within Australia. **K** Poorly known, field distribution information is inadequate. **Ca** adequately reserved with 1000 or more plants in a reserve. **Ci** inadequately reserved with less than 1000 plants in a reserve.

Category and Priority Codes in Pressey *et al.* (1990b). **3** Species restricted in the Western Division but also occurs interstate with **A**: few records, or **B**: many records. **4A** has disjunct occurrences in the Western Division with the main population interstate. **2** protection in the Western Division for these rare and/or threatened taxa is very important. **4** protection in Western Division is desirable to conserve the genetic variation within the ranges of the taxa.

Stands of Black Bluebush (*Maireana pyramidata*) and Pearl Bluebush (*Maireana sedifolia*) (communities 8 and 9) are reserved north of the mapped area in Mungo National Park. Forty per cent of the Park consists of the 'Mungo landsystem' (Walker 1991) dominated by these shrublands and Bladder Saltbush *Atriplex vesicaria*.

The Lowbidgee District has the best stands of Lignum (*Muehlenbeckia florulenta)* in New South Wales and possibly south-eastern Australia (Department of Water Resource 1991). A Plan of Management for the District by the Department of Water Resources (DWR) is near completion. Information from the draft of the management plan (DWR 1991) indicates that it is also one of the most significant wetland habitats for water birds, particularly ibis, in eastern Australia. As it is also highly productive agricultural land, clearing has removed 40% of Lignum in the last 20 years, the remainder is grazed. 'Protected lands' have been established but they do not preclude grazing activities. The water flow to the whole area is under control of the DWR. Smaller areas of Lignum occur along the Murray floodplain but have not been separated at this mapping scale (see Margules and Partners *et al.* 1990).

Conservation of species

Of all vulnerable plants in NSW, 44% occur on the western slopes and plains (Benson 1989). Pressey *et al.* (1990*b*) lists 239 plant taxa with restricted distributions in the Western Division. Of those, some species are considered endangered, vulnerable or rare (Briggs & Leigh 1988). Table 3 lists the species of conservation significance for the mapped area. Data for the rare or threatened species have been provided from ROTAP database (NSW National Parks & Wildlife Service).

Options for improving conservation

The two existing reserves conserve only a small part of the diversity of plant communities. The major conservation concerns result from the effects of the agricultural practices of grazing and clearing. The dedication of further areas as conservation reserves and the modification of land-management practices may improve the current situation.

Such improvement may be achieved by encouraging retention of native vegetation. Fencing off areas of native vegetation to exclude stock and rabbits facilitates the regeneration of the tree and shrub species and helps to restore the understorey. This is particularly necessary for the survival of the *Callitris* Mixed Woodland on the source-bordering dunes. Retention of native vegetation also is a means of preventing salinisation and soil loss.

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APPENDIX 1

Species list for communities identified on the Balranald – Swan Hill 1:250 000 map sheet. (Key on page 652).

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
PTERIDOPHYTES					
Adiantaceae					
Cheilanthes austrotenuifolia			4		
Azollaceae					
Azolla filiculoides	1				e
Marsileaceae					
Marsilea drummondii	1 2				
M. hirsuta					a
GYMNOSPERMS					
Cupressaceae					
Callitris glaucophylla		3b	4 16		
C. preissii subsp. *murrayensis*			16 20		
C. verrucosa		3b			
ANGIOSPERMS					
Aizoaceae					
Disphyma crassifolium subsp. *clavellatum*	1 2			11	
Glinus lotoides	1 2				
**Psilocaulon tenue*		3c3d	4		
Tetragonia tetragonioides	2	3c3d	4	9 21	
Amaranthaceae					
Alternanthera denticulata	1 2				
A. nodiflora	2				ac
**A. pungens*					a
A. sp. *A*				17	
Amaranthus macrocarpus	1				
Ptilotus atriplicifolius					
P. exaltatus var. *exaltatus*		3b			bc
P. nobilis		3c			
P. obovatus var. *obovatus*			17		
P. seminudus		3c			c
P. spathulatus		3b3c	4 17		
Apiaceae					
Daucus glochidiatus	2	3b	4 17	8 9 11 21	
Eryngium plantagineum					a
Asclepiadaceae					
Marsdenia australis		3c			
Asteraceae					
Actinobole uliginosum		3b	4 16 17	9	
Angianthus brachypappus				11	
A. tomentosus		3d			

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Asteraceae (cont'd)					
**Arctotheca calendula*		3c	4		
**Aster subulatus*					ab
Brachycome basaltica var. *gracilis*	1		4	23	
B. ciliaris var. *ciliaris*		3b3d	4	8	
B. goniocarpa	2				a
B. gracilis	2				a
B. lineariloba	2	3b3c	4 17	8 9 11 19	
B. papillosa					g
B. trachycarpa	3c				
Bracteantha bracteata [*Helichrysum bracteatum*]			4 17		
Calocephalus sonderi	1 2		4 16	11 21	
Calotis cuneifolia	1 2				a
C. erinacea					a
C. hispidula		3b3c3d	4	8 9	
C. scabiosifolia var. *scabiosifolia*	2				c
C. scapigera	af	2			
**Carthamus lanatus*	1		17		
Cassinia arcuata					b
**Centaurea melitensis*	2	3d	4 17	8 9 22	
Centipeda cunninghamii	1 2			22 23	
C. minima	1				aef
C. thespidioides	2				ac
**Chondrilla juncea*	1				
Chrysocephalum apiculatum [*Helichrysum apiculatum*]		3b	16		cd
**Cirsium vulgare*	1 2			22 23	
**Conyza bonariensis*	1				
Cotula australis	1 2				
**C. bipinnata*				11 21	
C. coronopifolia				23	e
Cymbonotus lawsonianus	1 2				a
Dittrichia graveolens	1				af
Eclipta platyglossa	1 2				
Elachanthus pusillus		3d			c
Epaltes australis	1 2				a
E. cunninghamii					a
Eriochlamys behrii				8 11	
Gnaphalium sphaericum	2		4		ac
**Hedypnois rhagadioloides* subsp. *cretica*			4 17	8 9 22	
Helichrysum leucopsideum		3c			b
Hyalosperma demissum [*Helipterum demissum*]	2				c

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Asteraceae (cont'd)					
H. semisterile [*Helipterum jessenii*]	2		17	9 11	
**Hypochaeris glabra*	1 2	3b	4 5 17	8 9 11	
**H. radicata*	2		4	9	c
Isoetopsis graminifolia	2	3b3c		9	abcd
Ixiolaena chloroleuca					a
I. leptolepis				21	
**Lactuca serriola*	1 2				a
Leucochrysum molle [*Helipterum molle*]			4		c
Microseris lanceolata				11	
Millotia myosotidifolia	1				a
Minuria cunninghamii			4 17	9 11 21	
M. integerrima	2				ac
M. leptophylla			17	8 9	
Myriocephalus rhizocephalus	2			11	
M. stuartii		3b	16		ac
Olearia lepidophylla		3b			
O. magniflora		3b	4		b
O. muelleri		3a3b3c	4		
O. pimeleoides	2	3b3c	4		
O. rudis					d
**Onopordum acaulon*	2				
**Picris sp.*	1				e
Podolepis canescens		3b			f
P. capillaris		3b			
P. jaceoides		3c			
P. muelleri				11	
Podotheca angustifolia		3b			
Pogonolepis muelleriana			17	9 11 19	
Pseudognaphalium luteoalbum	1				ab
Pycnosorus pleiocephalus [*Craspedia pleiocephala*]			17	8 9 19	
**Reichardia tingitana*			17	22	
Rhodanthe corymbiflora [*Helipterum corymbiflorum*]	2	3b	4 17	8 9 11 19 21	
R. diffusa [*Helipterum diffusum*]					d
R. floribunda [*Helipterum floribundum*]	2		4	8	
R. pygmaea [*Helipterum pygmaeum*]			4 17		
R. stuartiana [*Helipterum stuartianum*]		3c3d	4 16 17	8 9 21 22	
R. tietkensii [*Helipterum tietkensii*]					g

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Asteraceae (cont'd)					
Senecio cunninghamii	1			18 23	be
S. glossanthus	2	3b3c3d	4	8 9 11	
S. lautus subsp. _dissectifolius_					b
S. murrayanus					g
S. quadridentatus	1 2	3b			
S. runcinifolius	1 2		4		
*_Sonchus asper_ subsp. _glaucescens_	1				ae
*_S. oleraceus_	1 2	3b3c3d	4 17	8 9 11 19 22	
Triptilodiscus pygmaeus [_Helipterum australe_]	2		4		
*_Urospermum picroides_					a
Vittadinia cervicularis		3b			
V. cervicularis var. _cervicularis_	2	3b3c3d	4 16		
V. condyloides			4 17		
V. cuneata var. _cuneata_	2				
V. dissecta var. _hirta_	2	3b	4		
V. gracilis	1 2				
V. pterochaeta			9		
Waitzia acuminata		3b			c
*_Xanthium occidentale_	1		23		aef
*_X. spinosum_	1			18 21 23	
Boraginaceae					
*_Echium plantagineum_	1 2	3c	4	21	
Halgania andromedifolia		3b	4		bd
H. cyanea		3b			
*_Heliotropium europaeum_	1			9	
*_H. supinum_	1 2			18 23	
Omphalolappula concava	2	3b3c3d	4 17	9	
Plagiobothrys elachanthus					a
Brassicaceae					
*_Alyssum linifolium_		3c	4		
Arabidella trisecta		3c			
*_Brassica tournefortii_	1 2	3b3c3d	4 17		
*_Carrichtera annua_		3b3c3d			
Geococcus pusillus	2		4		ac
Harmsiodoxa blennodioides					
*_Lepidium africanum_					ab
L. leptopetalum		3c	4		
L. monoplocoides					g
L. papillosum					a
L. phlebopetalum					a
L. pseudohyssopifolium				21	
Pachymitus cardaminoides					adg
Rorippa laciniata	1		23		e
*_Sisymbrium erysimoides_	1 2	3d	4 17	19	

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Brassicaceae (cont'd)					
**S. irio*	1	3b3c3d	4		
**S. orientale*	2	3c	4		
Stenopetalum lineare		3b3d			
Callitrichaceae					
Callitriche cyclocarpa					g
Campanulaceae					
Wahlenbergia communis			17		
W. fluminalis	1 2	3b3c			
W. gracilenta			9		ac
W. luteola			4 16 17		
Caryophyllaceae					
**Herniaria cinerea*		3d		9	
**Polycarpon tetraphyllum*					a
**Scleranthus minusculus*		3b	17		
**Silene apetala*		3b3d	4 17	11 19	
**S. gallica*		3b	4		
**S. longicaulis*					a
**S. nocturna*					a
**Spergularia diandra*	2		4	8 11 19	
**S. rubra*	2		4 17	8 11 21	
Casuarinaceae					
Allocasuarina luehmannii			16 20		
Casuarina pauper			4 16	8	
Chenopodiaceae					
Atriplex acutibractea					
subsp. *acutibractea*		3c3d			
A. angulata		3c		8 9	
A. conduplicata			4	8 11	
A. eardleyae	2	3c	4	9	
A. holocarpa				9	bc
A. infrequens	2				
A. leptocarpa	2		4	21	
A. lindleyi	2	3c	4 17	8 9 19 11 21 22	
A. nummularia	1 2	3c3d		9 19 11	
A. pseudocampanulata	2		17	19 11 21 22	
A. semibaccata	1 2	3b3c	4	21 23	
A. spinibractea					b
A. stipitata	2	3b3c3d			
A. suberecta	2				
A. vesicaria		3b3c3d	4	8 9 19 11 21	
**Chenopodium album*					b
C. cristatum					a
C. curvispicatum	2	3b3c3d	4	9	
[*Rhagodia gaudichaudiana*]					
C. desertorum					
subsp. *microphyllum*	2	3b3c	4 16		

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Chenopodiaceae (cont'd)					
**C. murale*	2				
C. nitrariaceum	1 2		4	11	
C. pumilio	1 2				
Dissocarpus biflorus var. *biflorus*			9 19 11		
D. paradoxus		3c3d	4	8 9 21 22	
Dysphania glomulifera	1				a
Einadia nutans	1 2	3b3c	4 16	9 19 21	
Enchylaena tomentosa	1 2	3b3c3d	4 16	8 9 19	
Halosarcia pergranulata	2				a
Maireana aphylla		2		4	9 21
M. appressa		3b	4	22	
M. brevifolia	2	3b3c3d	4	21	
M. ciliata	2		4	9	ac
M. coronata				21?	
M. decalvans	2	3a	4	21	
M. enchylaenoides		3b			c
M. erioclada		3b3c3d			
M. georgei		3c		8 9	
M. pentagona	1 2			21	
M. pentatropis		3b3c3d	4		
M. pyramidata	2	3c3c3d	4 16	8 9 19 22	
M. radiata		3b3c3d	4	9	
M. sclerolaenoides		3b3c3d	4 17	9 21 22	
M. sedifolia	2	3b3c		8 9	
M. trichoptera			4		b
M. triptera		3b3c3d	4	8	
M. turbinata		3d	4 16	8 22	
Malacocera tricornis	2			8 11 19 21	
Neobassia proceriflora					a
Osteocarpum acropterum var. *deminuta*	2		4	8 19	
[*Babbagia acroptera*]					
Pachycornia triandra	2				a
Rhagodia spinescens	2	3a3b3c3d	4 16	8 19 22	
R. ulicina		3b			
Salsola kali	1 2	3b3c3d	4	21	
Scleroblitum atriplicinum	2		4		
Sclerolaena bicornis		3c	4?	9 11	
S. brachyptera	2		4	8 9 11 19 21	
S. diacantha	2	3b3c3d	4 17	8 9 11 21	
S. divaricata	2		4	11 19	
S. intricata				11	
S. limbata					g
S. muricata	1 2			18 11 19 21 22 23	

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Chenopodiaceae (cont'd)					
S. obliquicuspis	2	3b3c3d	4	8 9	
S. parviflora		3b			
S. patenticuspis	3c		9		cf
S. stelligera					a
S. tricuspis	2	3b	4	8 11 19	
S. ventricosa					b
Sclerostegia tenuis				11	
Convolvulaceae					
Convolvulus erubescens	1 2		4 17	8 9	
C. remotus			17		
Cressa cretica	2				a
Crassulaceae					
Crassula colorata var. *acuminata*	2	3c	4 17	9 19 21	
C. decumbens var. *decumbens*	2				a
C. sieberiana	1 2	3c	4		
Cucurbitaceae					
**Cucumis myriocarpus*	2				
Euphorbiaceae					
Adriana hookeri					c
Beyeria opaca		3c			b
Chamaesyce dallachyana	1				e
C. drummondii	1 2			9	
Euphorbia planiticola	2				c
Phyllanthus lacunarius	2				
Fabaceae-Caesalpinoideae					
Senna artemisioides notho subsp. *coriacea* [*Cassia eremophila* var. *coriacea*]		3b			
Senna artemisioides subsp. *filifolia* [*Cassia eremophila* var. *eremophila*]		3a3b3c	4		
Senna artemisioides subsp. *petiolaris* [*Cassia eremophila* var. *platypoda*]		3c	4 16		
S. artemisioides subsp. *zygophylla* [*Cassia eremophila* var. *zygophylla*]		3c	4 17		
S. artemisioides subsp. *zygophylla* x *sturtii*			16		

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Fabaceae-Faboideae					
Bossiaea walkeri		3a3b3c			
Daviesia arenaria		3b			
Eutaxia microphylla		3b			bf
Lotus australis	1				a
L. cruentus	1		4		ac
**Medicago laciniata*		3c	4 17	22	
**M. minima*	1 2	3c	4 17	9	
**M. polymorpha* var. *vulgaris*	1 2	3c3d	4	19 21 22	
**M. praecox*	1		4	8 9 11 19 21	
**M. truncatula*		3c	4 17	8 11	
**Melilotus indica*	1				e
Psoralea cinerea					a
P. pallida					a
P. tenax	1 2				a
Swainsona microphylla	1				a
S. murrayana					g
S. phacoides					a
Templetonia egena		3b3c	4 17	8	
T. sulcata					g
**Trifolium arvense*			17		
**T. subterraneum*	1				e
**T. tomentosum*				22	
Fabaceae-Mimosoideae					
Acacia aneura			4		b
A. brachybotrya		3b	16		
A. buxifolia subsp. *buxifolia*		3b			
A. colletioides		3a3b3c	4		
A. hakeoides		3c			
A. halliana		3c	16		
A. ligulata	2	3b3c	16		
A. melvillei		3c	4 16 17		
A. microcarpa		3b3c			b
A. nyssophylla					a
A. oswaldii	2	3b3c3d	4 16 20	8	
A. rigens		3a3b	4		
A. salicina	1		16		
A. sclerophylla	2	3b3c			
A. stenophylla	1 2			18	
A. victoriae		3b3d		22	
A. wilhelmiana		3b			
Frankeniaceae					
Frankenia serpyllifolia	2			11	
Fumariaceae					
**Fumaria densiflora*	2				a
Gentianaceae					
Centaurium spicatum	1 2				a

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Geraniaceae					
**Erodium cicutarium*	2	3c	4	9 21	
E. crinitum	1	3b3c	4 17		
Geranium retrorsum	1 2				a
Goodeniaceae					
Goodenia fascicularis			17	9	
G. glauca	1 2				aef
G. heteromera	1				a
G. pinnatifida	2		4	8	
G. pusilliflora	2	3b	4	9 19	
G. sp. (mallee *Goodenia*)		3b			
Scaevola spinescens					a
Gyrostemonaceae					
Codonocarpus cotinifolius		3b			
Haloragaceae					
Haloragis aspera	1 2				a
H. glauca	1				f
H. odontocarpa					bd
H. odontocarpa f. pterocarpa		3b			c
Myriophyllum caput-medusae	1			23	e
M. verrucosum	2			23	ef
Lamiaceae					
Ajuga australis	1 2				a
**Marrubium vulgare*	1 2	3c			
**Salvia verbenaca*		3b3c	4		
**Stachys arvensis*	1				e
Teucrium racemosum	1 2		17		
Westringia rigida		3b3c3d	4		
Lauraceae					
Cassytha melantha		3b			
Linaceae					
Linum marginale					b
Lobeliaceae					
Pratia concolor	1 2			23	
Loranthaceae					
Amyema linophyllum subsp. *orientale*	2		4		
A. miquelii	1 2	3b3c	4		
A. miraculosum subsp. *boormanii*		3b			f
A. preissii	2	3b		8	
A. quandang var. *quandang*					
Lysiana exocarpi subsp.*exocarpi*			16		
Lythraceae					
Ammannia multiflora var. *multiflora*					a

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Lythraceae (cont'd)					
Lythrum hyssopifolia	1 2				a
Malvaceae					
Abutilon theophrasti	2				f
Lavatera plebeia	1		4	8	
Lawrencia squamata		3d		9	
**Malva parviflora*	1 2		4	19 21 23	
Sida ammophila	2				a
S. corrugata	2		4		
S. cunninghamii			17		
S. fibulifera	2				a
S. filiformis				21	
S. trichopoda	1 2			21	
Menyanthaceae					
Nymphoides crenata	1				e
Myoporaceae					
Eremophila bignoniiflora					a
E. deserti		3b			
E. divaricata	1 2				af
E. glabra		3b3c	4		
E. longifolia	2		4		
E. maculata		3b			b
E. oppositifolia					b
E. polyclada					a
E. sturtii			4 16	8	
Myoporum parvifolium	1 2				a
M. platycarpum		3a3b3c3d		4	
Myrtaceae					
Baeckea crassifolia		3b			bc
Eucalyptus camaldulensis	1 2			18	
E. costata		3a3b			
E. dumosa		3a3b3c3d			
E. gracilis		3a3b3c3d			
E. intertexta	2				
E. largiflorens	1 2				
E. leptophylla		3b3d			
E. oleosa		3a3b3c3d			
E. porosa		3d			
E. socialis		3a3b3c3d			
E. socialis x oleosa		3c			
Melaleuca lanceolata	2				
Nitrariaceae					
Nitraria billardierei	2	3b3c3d	4	9 18 21 22 23	
Nyctaginaceae					
Boerhavia coccinea [*B. diffusa*]	2				

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Oleaceae					
Jasminum lineare			16		
Onagraceae					
Epilobium hirtigerum				23	e
Ludwigia peploides subsp. *montevidensis*	1			23	e
Oxalidaceae					
*Oxalis corniculata	2	3b3c	4		
O. perennans	1 2		4 16 17	8 9 21	
*O. pes-caprae					b
Papaveraceae					
*Papaver hybridum			4		bd
Pittosporaceae					
Billardiera versicolor					b
Bursaria spinosa			16		
Pittosporum phillyreoides	2	3b3c	4 16	8 9	
Plantaginaceae					
Plantago cunninghamii	2		4 16 17	21	
P. drummondii			17	8 9 11 21	
Plumbaginaceae					
*Limonium lobatum		3c	4		
Polygonaceae					
*Emex australis			4		b
Muehlenbeckia florulenta	1 2			18	
M. diclina					g
Persicaria decipiens	1			23	ae
P. lapathifolia	1				a
P. orientalis	1				e
P. prostrata	1				aef
Polygonum plebeium	1				af
Rumex brownii	1				
*R. crispus				23	e
R. crystallinus	1				a
R. tenax	2			21	
Portulacaceae					
Calandrinia calyptrata	2				a
C. eremaea	2	3b3c3d	4 17	19	
C. volubilis	2				a
Portulaca oleracea					b
Primulaceae					
*Anagallis arvensis	1 2				a
Proteaceae					
Grevillea huegelii		3a3b3c			
Hakea leucoptera		3c	16 17		
H. tephrosperma		3c	16		
Ranunculaceae					
Clematis microphylla var. *microphylla*	2				f

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Ranunculaceae (cont'd)					
**Myosurus minimus* var.*australis*	1				af
Ranunculus inundatus	1				e
R. lappaceus	1				
R. pentandrus var. *platycarpus*	1 2				a
R. pumilio	2				f
R. undosus	1				e
Rubiaceae					
Asperula conferta	1 2				
A. geminifolia	1				f
**Galium aparine*	1 2				
Opercularia turpis					dg
Synaptantha tillaeacea	1				f
Rutaceae					
Geijera parviflora			4 16 20		
Salicaceae					
**Salix babylonica*	1				a
Santalaceae					
Exocarpos aphyllus	2	3c	4	8	
E. sparteus		3b			bg
E. strictus	1 2				
Santalum acuminatum			4		
S. murrayanum		3b3c			f
Sapindaceae					
Alectryon oleifolius subsp. *canescens*		3c	4 16 20		
Dodonaea viscosa subsp. *angustissima*	2	3b3c	4 16 20		
Scrophulariaceae					
Limosella curdieana					b
Stemodia florulenta	1 2	3b		8	
**Verbascum virgatum*					b
Solanaceae					
**Datura inoxia*	1				f
Lycium australe			4		bd
**L. ferocissimum*	2		4 16 17		
**Nicotiana glauca*		3b		23	
N. velutina	2				a
Solanum coactiliferum		3b			
S. esuriale	1 2		17	9 21	
S. karsensis					g
**S. nigrum*	1 2				ae
S. simile	1				a
Sterculiaceae					
Brachychiton populneus					a

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Thymelaeaceae					
Pimelea microcephala subsp. *microcephala*			16		
P. simplex subsp. *continua*		3b	16		
Urticaceae					
Parietaria debilis			4		cd
**Urtica urens*	1				e
Verbenaceae					
**Phyla nodiflora*	1 2				a
**Verbena officinalis*	2				
**V. supina*	1				
Zygophyllaceae					
Tribulus terrestris	2			21	
Zygophyllum ammophilum	2	3c3d	4	9	bc
Z. angustifolium			17		
Z. apiculatum		3b3c3d	4		
Z. aurantiacum		3b3c3d	4		
Z. confluens		3b3d	4	8 9	
Z. crenatum		3d		8 9	
Z. eremaeum		3b3c3d	4 17		
Z. glaucum		3b3c		21	
Z. iodocarpum	2	3c3d	4 17	8	
Z. ovatum		3c3d	4	8	
MONOCOTYLEDONS					
Alismataceae					
Damasonium minus	1				e
Amaryllidaceae					
Calostemma purpureum					a
Anthericaceae					
Arthropodium minus				9	c
Thysanotus baueri			17		
T. patersonii		3b			f
Asparagaceae					
**Asparagus officinalis*	1 2				a
Asphodelaceae					
**Asphodelus fistulosus*	1 2	3b			
Bulbine alata			17	9	
B. bulbosa					
B. semibarbata			17	8 11	
Colchicaceae					
Wurmbea dioica					d
Cyperaceae					
Carex appressa	1				e
Cyperus exaltatus	1				af
C. flaccidus					

Botanical name	Community				Other Records
	forest	mallee	w'land	shrub/grasslands	
Cyperaceae (cont'd)					
C. gymnocaulos	1 2				af
C. pygmaeus					a
C. squarrosus					a
Eleocharis acuta	1 2				
E. pallens				11 13	
E. pusilla	1				e
Gahnia lanigera		3b			f
Isolepis marginata					a
I. platycarpa	1				a
Hypoxidaceae					
Hypoxis glabella var. *glabella*					b
Juncaceae					
**Juncus aridicola*	1			13	
J. flavidus	1			23	e
J. radula				23	
Juncaginaceae					
Triglochin centrocarpa					a
T. procera	1				e
Phormiaceae					
Dianella longifolia	2	3b			
Poaceae					
Agrostis avenacea	1 2		4	11 21 23	
**Alopecurus geniculatus*	1				e
Amphibromus sp.	1				e
Amphipogon caricinus					d
Aristida behriana			17	19	
**Avena barbata*	2			9 21 15	
**Avena fatua*					
Bromus arenarius	2			19 11	
**B. diandrus*			4	22	
**B. madritensis*				9	
**B. molliformis*			4		c
**B. rubens*	2	3b3c3d	4 16 17	8 9 11 19 21 22	
Chloris truncata	2			9	
Cynodon dactylon	1 2				
Danthonia caespitosa	1 2	3b	4 16 17	8 9 11 19 21 22	
D. eriantha			17		
D. setacea	1 2				a
Digitaria ammophila					a
Enneapogon avenaceus	2				
Enteropogon acicularis	2		4 17		
Eragrostis australasica	1 2			11 19 21 13	
E. dielsii				8	
E. elongata	1				a
E. lacunaria	1 2				a
**E. pilosa*	2				c

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Poaceae (cont'd)					
Eriochloa pseudoacrotricha	2				c
Eulalia aurea	1				a
Homopholis proluta				8	
**Hordeum hystrix*	2				c
**H. marinum*	1 2				a
**H. leporinum*	1 2	3b3c3d	4 17	8 9 11 19 21 23	
**Lamarckia aurea*	2			19 11	
**Lolium perenne*	1 2	3d		8 19 21	
**Panicum coloratum*	1				
Paspalidium constrictum				9	
P. jubiflorum	1 2				
P. distans	1				e
Paspalum distichum	1			23	ae
**Pentaschistis airoides*	1 2		16		a
**Phalaris minor*	1				e
**P. paradoxa*	1 2		4	11 18 21	
Phragmites australis	1			23	
Poa fordeana	1 2				
P. labillardieri	1				a
**Polypogon monspeliensis*				18 23	e
Pseudoraphis spinescens	1				a
**Puccinellia ciliata*				11	
**Rostraria cristata*	1 2			22	
**Rostraria pumila*	2		4	19	
**Schismus barbatus*	1 2	3c3d	4 16		
Sporobolus caroli				9	c
S. mitchellii	1 2				a
Stipa acrociliata		3b3c			c
S. elegantissima		3b3c	4 17	8 9 19 22	
S. eremophila			4 17	22	
S. metatoris					g
S. mollis		3b			
S. nitida	1	3c3d	4 16	8 9	
S. nodosa	2	3d	4 17	8 9 21 22	
S. platychaeta		3c			
S. scabra		3b			
S. scabra subsp. *scabra*	2				
S. trichophylla	1	3b			
S. wakoolica					g
Triodia scariosa		3b			
**Triticum aestivum*	1				a
**Vulpia myuros*	1 2	3d	16	11 21	
Potamogetonaceae					
Potamogeton tricarinatus	1				e

Botanical name	**Community**				**Other Records**
	forest	mallee	w'land	shrub/grasslands	
Typhaceae					
Typha domingensis				23	
T. orientalis	1			23	
Xanthorrhoeaceae					
Lomandra glauca		3b			f
L. leucocephala subsp. *robusta*		3b3c	4		bd
L. leucocephala subsp. *leucocephala*		3b			

Key

[ ] names in square brackets are synonyms.

a = Margules and Partners Pty Ltd, P. & J. Smith Ecological Consultants, & Department of Conservation Forests and Lands Victoria (1990) *River Murray riparian vegetation study* (Murray-Darling Basin Commission).

b = Morcomb L. & Westbrooke M., (1990). The vegetation of Mallee Cliffs National Park. *Cunninghamia* 2(2):147-165.

c = M. Fox study sites. Unpublished data (Royal Botanic Gardens, Sydney).

d = W.S. Semple (1979) *Species list for "Mallee Cliffs"* Soil Conservation Service of NSW

e = Pressey, R.L., Bell, F.C., Barker, J., Rundle, A.S. & Belcher, C.A. (1984) *Bio-physical features of the Lachlan-Murrumbidgee confluence, south-western New South Wales.* (N.S.W. National Parks and Wildlife Service).

f = A. Parsons (Unpublished species list for the area south of Mallee Cliffs National Park to the Murray River (NSW National Parks & Wildlife Service, Sydney).

g = Species of particular conservation significance within the mapped area (see Table 3).

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A national register for the fire responses of plant species

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Abstract

Gill, A. Malcolm[1] & Bradstock, R.A.[2] ([1] CSIRO Division of Plant Industry, GPO Box 1600, Canberra, ACT, Australia 2601; [2] NSW National Parks and Wildlife Service, PO Box 1967, Hurstville, NSW, Australia 2220) 1992. *A national register for the fire responses of plant species.* Cunninghamia *2(4): 653–660.* Currently, approximately 1 500 vascular plant species have been classified in relation to their fire responses and included in a national fire response register. In a cooperative scheme to which new contributors are welcome, data are being assembled in order to assist in the development of practical scientifically-based monitoring systems for fire-prone plant species. Other uses of the data are to discover species which show ecotypic variation; or, show varying responses depending on the nature of the fires or environments to which they are exposed. The data collated also may be used to help explain ecosystem dynamics through models (e.g. Noble & Slatyer 1980). Fire-response categories are based on the schemes of Noble & Slatyer (1980) and Gill (1981 *a* & *b*). Further data being collated are for life form, conservation status and longevity.

Introduction

Knowledge of the responses of plant species to fires is of intrinsic interest but the information can be used also in the development of practical, soundly-based monitoring systems for fire effects in state forests, national parks and nature reserves. In a pilot system developed for Nadgee Nature Reserve, Gill & Nicholls (1989) used response data for species collected by observers not just at Nadgee but also at other sites, sometimes in other States. This paper reports the initiation and development of a fire response register to facilitate the accumulation and transfer of knowledge across Australia as a means towards the establishment of scientifically based, but practical, monitoring systems for vascular plant species in state forests, parks and reserves. An urgent priority for the fire management of native landscapes today is for effective monitoring systems; with their development and implementation, resource managers will be able to demonstrate their success in the management of plant-species biodiversity.

The aims of this paper are:

(i) to describe the nature of the data being collected and collated;

(ii) to provide the rationale for the adoption of categories of data chosen;

(iii) to examine some of the difficulties involved in classifying certain species and, thereby, encourage study of their autecology;

(iv) to advise scientists and naturalists of the establishment of the register and invite contributions to it.

The register

The register categorises the responses of species to fires but does not provide the basis for the prediction of *population* behaviour in relation to fire regimes (combinations of frequencies, intensities and times of occurrences of fires) in a detailed quantitative way. Nonetheless, the sort of classification described here may flag extreme responses of species to particular fire regimes, such as extinction due to the occurrence of a fire before the onset of flowering in a fire-sensitive species.

Nomenclature for the register follows that of the recent National Checklist of Australian vascular plant species compiled by Hnatiuk (1990). Before entry into the register, species names are standardised according to the national checklist.

Data recorded in the register are:

(i) species (from checklist) - family, genus, species;

(ii) life form - tree, shrub, non-geophytic herb or graminoid, geophyte, epiphyte (including mistletoes);

(iii) fire-response - fire-response category and observer's name;

(iv) longevity - annual, biennial, perennial;

(v) origin - native, exotic;

(vi) other available data, e.g. response at a particular life-cycle stage (seedling, immature, adult, senescent - an additional line entry), primary juvenile period in years after fire for particular areas (local data only as subject to local variation) and special-case fire-regime vulnerability. Whether the species is rare or threatened (Briggs and Leigh 1988) would be identified from current lists.

Which classification of species responses?

There are many species classifications for species in fire-prone environments. They may be divided into three groups: (i) mechanistic; (ii) consequential; (iii) strategic.

'Mechanistic' classifications attempt to group species which have similar means of resistance and recovery in the face of fire. An example of this is the classification of Gill (1975) which distinguishes, among other things, plants that owe their immediate resistance to the thermal properties of a layer of bark or to those of a stem with dispersed vasculature.

'Consequential' classifications are unconcerned with mechanism; the end result is all that matters. An example of this is the scheme devised by Noble and Slatyer (1980) which concerns itself with, among other things, whether or not plants survive a fire rather than how that occurs.

'Strategic' classifications are those which imply behavioural action and tend to be evolutionary in perspective: examples are the classifications of Rowe (1983) and Frost (1984). These distinguish species which are 'evaders', 'resisters', 'endurers', etc. (see also Naveh 1975).

The three approaches outlined above are, in fact, not completely distinct; there are many intermediates and, indeed, the different systems often use similar criteria in arriving at their classifications. Perhaps the mechanistic approach is the most distinct at present. The most comprehensive classification is that of Noble and Slatyer (1980) which includes not just the way a species survives a disturbance, but also its ability to become established and the timing of important events during its life history. No one scheme completely satisfies all users (and uses), nor, perhaps, all circumstances and all levels of knowledge of species' properties.

'Adaptive traits', 'vital attributes' and 'species characteristics'

The most enduring criterion for species response to fires is whether persistence through the event is by seed ('seeders'), or by vegetative means ('sprouters') (e.g. Jarrett & Petrie 1929). Given exposure to the same level of leaf damage (explicit in the classification of Gill (1981*a*) as 100% leaf scorch, but rare elsewhere), most species seem to fall quite readily into one or other of these categories. Even without explicit attention to the level of damage, many species may be readily classified. Beadle (1940), for example, listed the percentage survivals of plants belonging to 13 shrub species without specifying any level of damage: 11 species recorded either 100% death or nil death while the other two were within 12% of these extremes. However, there are species which do have intermediate responses which cannot be attributed to extrinsic factors: Hodgkinson and Griffin (1982) noted that, among the 13 shrub species they observed, mortalities of populations of 10 species were mostly within the range 0–30% or 70–100% while the remaining three species had intermediate mortalities. As a general rule, if mortality within the population with 100% leaf scorch is greater than 70%, then the species would be a 'seeder' species; if mortality is less than 30%, it would be a 'resprouter' species. If there is any doubt into which category a species should be placed, because of intermediate behaviour, the species is better put into both categories with annotation (with a two-line entry into the register).

One expected outcome of the register is to find species which have different responses in different places. In some cases such finds may lead to the discovery of new species such as the *Hakea* species studied by Lee (1984). In other cases, such as hummock grass *Triodia irritans* found in semi-arid NSW and Victoria, resprouting has been observed near Mt Hope, NSW, and in Wyperfeld National Park in northwestern Victoria, but complete mortality has been observed to be a consequence of fire elsewhere (Bradstock 1989). A forest example is *Acacia dealbata* which in mesic forest areas is a 'seeder' but elsewhere is a 'resprouter'(Ashton 1981).

Naveh (1975), in Israel, distinguished three categories of species, viz. 'facultative root resprouters'(termed 'resprouters' here), 'obligatory seed regenerators' (termed 'seeders' here) and 'obligatory root resprouters'. The last of these categories was for species which did not reproduce from seed after fire but did do so vegetatively (i.e. a subsection of 'resprouters'). We do not know whether or not 'obligatory root resprouters' fail to regenerate from seed because there is none available at the appropriate time or because seed present is not stimulated to germinate. The simplest hypothesis is that there is no seed available. If so, knowing that a species falls into this category has particular value in predicting species response to a rare extreme drought (or bulldozing, for example) which may kill the vegetative population. However, classifying a species into this category is difficult because it implies that the reproductive behaviour of the species through time is well known: species with episodic regeneration may seem to be bereft of a seed supply most of the time but may depend on a rare reproductive event for the long-term replenishment of the population.

Noble & Slatyer (1980) and Gill (1981*a*) subdivided the seed regenerators into three identical groups, viz. those that depend on external sources of seed for their representation in the burned area, those that depend on seed stored in the soil for regeneration, and those that depend on canopy-stored seed. The diaspores of species in these three groups show particular morphologies and means of responses to fires, such as hard seededness (many leguminous species - Auld & O'Connell 1991), succulent fruits assisting dispersal (e.g. mistletoes), and containment in large woody fruits (e.g. *Hakea* species). It is tempting to subdivide those species that disperse seed back into an area after fire according to the nature of the diaspore (winged seed, succulent fruit, spore) but the numbers of species involved are small and, therefore, subdivision may be unwarranted. Noble & Slatyer (1980) also had another group which may be seen as a subgroup of those that depend on seed for regeneration; this 'subgroup' was for species that had no available seed storage while the plant was in the juvenile stage (only), a useful subgroup for species such as the annual *Sorghum* species of the Northern Territory which can be eliminated locally by deliberate application of fire in the wet season (Stocker & Sturtz 1966).

We draw attention to a class of species with canopy-stored seed which seems to have been little discussed morphologically. Previously, the canopy-store category has been thought of as containing only species with woody fruits which protected the seed from fire during its passage. However, there are certain *Acacia* species which, when their pods split and reflex, expose seeds which remain on the canopies for considerable periods (O'Dowd & Gill 1986). This seed is likely to be vulnerable to fire. Some of these *Acacia* species, at least, would be expected to have seed stored in the soil as well, and would be best characterised on this basis rather than on canopy storage if the host plants are fire sensitive. An extreme case of this seems to be *Acacia cyclops*, a shrub of coastal areas of Western Australia and South Australia. *A. cyclops* shows storage of seed on canopies for long periods (O'Dowd & Gill 1986) but few seeds stored in the soil, apparently because seeds in soil are destroyed by hemipteran predators (Gill & Neser 1984). In Australia, it would be classified best, on the basis of present knowledge, as a 'seeder' reliant on external seed sources for its re-establishment. In South Africa where it is introduced, however, it would be characterised best as a 'seeder' species with soil-stored seed; there, it stores considerable quantities of seed in soil (see Gill & Neser 1984). These classifications for *A. cyclops* assume that any seed present on the bush at the times of fires would be destroyed or killed. Canopy seed storage also occurs in *Gahnia melanocarpa*, a robust, stemmed sedge, which displays persistent small seeds on thin threads dangling from the parent inflorescence; in this case, however, *Gahnia* is a species which usually survives fire and regrows from terminal buds - a 'resprouter'.

Among the vegetatively regenerating species, Gill (1981*a*) distinguished four categories viz. those regenerating from basal buds, root suckers, epicormic shoots (from aerial stems), or from large aerial apical buds unaffected by the fire. Regeneration from basal buds was distinguished from regeneration by root suckers because the latter have the potential for population growth after a fire event but the former do not. Mature plants regenerating from aerial sources comprised the last two categories of vegetatively regenerating plants: these were distinguished because the mechanisms of response are so different. Species which regenerate from epicormic shoots are trees or tall shrubs which may replenish their leaf populations quickly after fire and thereby shade their competitors. Species which regenerate from large apical buds, like many Xanthorrhoeaceae, may also have a fire-induced flowering response (Gill 1981*b*).

The fire-response categories distinguished for the purposes of the register may be determined from the key in Table 1. Note that while all categories in the table apply to woody plants, not all apply to herbaceous plants. In particular, there will be no entries for herbaceous plants in categories 1 and 6.

Table 1. Key for the classification of species according to their fire responses (after Gill 1981*a*).

Mature plants just subject to 100% leaf scorch from fire die (category 8 if no further data available):	
* Propagules present after fire's passage are in the form of viable canopy-stored seed	**Category 1**
* Propagules present after fire's passage are in the form of soil-stored seed	**Category 2**
* No propagules remain on the site after fire	**Category 3**
Mature plants just subject to 100% canopy scorch survive (category 9 if no further data available):	
* Resprout from root suckers or rhizomes	**Category 4**
* Resprout from basal stem buds such as those in lignotubers	**Category 5**
* Resprout from epicormic shoots	**Category 6**
* Regrowth from unharmed, usually terminal, aerial buds	**Category 7**

Additional data

The idea of the 'additional data' is that more detailed information than the species response only can be incorporated into the system. For example, if it is observed that a species at a particular life stage has a response that is different from that expected from the mature-plant response, then an extra entry can be made by repeating the species' name in the register (with life stage bracketed after it) and noting the response at that stage. A similar multiple entry can be made if there is a geographic variation in response (with geographic location bracketed) or a seasonal variation (with season bracketed).

The tolerance categories of Noble & Slatyer (1980) were considered for inclusion in the register but it was concluded that the level of detail they provide is beyond the broad scope of the purposes here defined. In the future, categories such as these may be worth including as the system moves towards a population level classification.

Further species data are needed if events such as the demise of populations of the annual tropical grass *Sorghum intrans* with a single wet-season fire (Stocker & Sturtz 1966) and the rapid depletion of mallee eucalypts with a series of annual or biennial autumn fires (Noble 1989) are to be predicted. While these events are unknown outside of deliberate human intervention, their occurrences have far reaching consequences.

In the case of annual *Sorghum* (Stocker & Sturtz 1966), the important point is that all propagules present were simultaneously vulnerable to fire at a particular stage of the life cycle. For the mallees, normally resprouters, vulnerability to a particular sequence of events occurred when all plants were at the same stage of regeneration and there was no seed present. Similarly, the 'obligate resprouters' may be seen as having populations which are synchronously vulnerable to particular events. Such circumstances as those described here in this section are considered to be, in general, beyond the resolution of the classification.

Life forms: vascular epiphytes

In our simple classification of life forms, we have included the category of 'vascular epiphytes' (taken broadly to include mistletoes) because of the special survival circumstances to which such plants may occur in relation to fires: they may be at various heights in the canopy of the host and, therefore, have positional protection (although they would have the same species response category as determined from Table 1); and, they may occur on host tissues with varying survival potential during fires. We know of no quantitative information on the fire responses of vascular epiphytes and their hosts.

Local use of the classification

Local use of the data in the register may involve the determination of juvenile periods, plant longevity and the minimum time interval between fires if predictions are to be made of local survivorship of the species given fires of an intensity sufficient to scorch plant canopies. For example, if the species has its entire population in the vegetative state and it is fire sensitive, then the population will become extinct when fire sufficient to scorch all the plant canopies occurs; if the population dies out before fire occurs, then it will become locally extinct also (assuming no seed in the soil in this case); if seed production occurs but is inadequate to completely replace the parent population when fire occurs, then repeated fires at the same interval will eventually cause the population to become extinct. Because of the importance of the fire interval of the most sensitive species, it is important to know the primary juvenile period (Gill 1975) of various species. This period varies from place to place (Benson 1985) but it is possible that the same two species at two different sites may have different juvenile periods but show the same relative chronology in coming to flower at each site.

The interval between fires varies widely from place to place and at the one site. A recent extreme occurred for heathland near Sydney when a small portion of an experimental site, burned a few weeks previously, was again burned when a severe unplanned fire occurred. Examples of two fires within a year are coming to light in the Sydney heathlands, such as in parts of the Royal National Park. Such examples are important because local declines, even extinctions, of vegetatively resprouting species could occur if short intervals between fires are repeated often enough (Bradstock & Myerscough 1988, Bradstock 1990). We know very little about relative sensitivities among resprouters to such events though there are parts of northern Australia that are routinely subject to annual fires.

Conclusions

This scheme is a national scheme but State nodes are envisaged which would collate and distribute State information. Already, people in Victoria, NSW, SA, Qld, WA and the ACT have indicated their willingness to take part in the scheme.

The national register, to date, has been compiled from unpublished sources as well as the literature. There are currently about 1 500 entries; most of the data are for mallee, heath and forest lands.

The State species check lists may be drawn from the master national checklists such that all contributors are working according to the same nomenclature. The system can operate on personal computers.

In the future, species response data to types of 'disturbance' other than fires are envisaged. Such data, fed into monitoring or other managerial systems, should provide managers with tools to assist them further in their management of our native landscapes. Eventually, demographic classes may be used to replace species' classification in designing monitoring systems.

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REVIEW

Vegetation description and map, Ipswich, south-eastern Queensland, Australia, scale 1:250 000.

J. A. Elsol, Queensland Botany Bulletin No. 10. Brisbane: Queensland Department of Primary Industries, 1991. 61 pp. + col. map, 92 x 58 cm. Price $22.00

Traditional vegetation survey and mapping, at times regarded as an old-fashioned methodology, is becoming increasingly attractive as land management agencies discover that such surveys provide an essential data source for their computerised database and geographical information systems. As a result, vegetation ecologists are being encouraged to carry out more vegetation mapping and site survey, providing data for the managers (hopefully!) to answer all sorts of difficult questions (both scientifically and politically), on land use and conservation issues.

This situation, however, also provides ecologists with an opportunity, indeed responsibility, to provide careful interpretation and assessment of such data particularly in terms of environmental impact and change, and long-term sustainable land use and conservation. Such assessments carry added weight in being made by the scientist possessing more contextual information than can readily be documented or databased (e.g. first-hand field inspection of many sites).

The Ipswich vegetation map shows 17 map units grouped and coloured according to structure. Each map unit consists of between one and eleven vegetation types. There are 33 woodland and open-forest vegetation types and a further seven closed-forest types. Each is described in detail in the accompanying text emphasising tree species – percentage frequency, basal area, species/site – but also with lists of small trees, shrubs and grasses, locations, altitude, geology, aspect and comments.

However, the scientist's interpretation and assessment are missing. There is no discussion of the nature of the vegetation of the map sheet in terms of community dynamics, viability or sustainability, or even conservation issues. This is an essential ingredient for making meaningful decisions if the data, clinically provided, classified and pigeon-holed, is to be plugged into a GIS, ready to provide *objective* answers.

This shortcoming appears to be related to the intent of the study i.e. *to overlook the last two centuries of human settlement by mapping the vegetation of the area as though it was in an 'undisturbed pre-European-settlement condition'* (p. 1). Whilst it is certainly appropriate to study and map an area in terms of its pre-European condition, much of the value in doing so is as a basis for interpreting current and recent-past vegetation and land use patterns. Much of the understanding that the researcher gains in doing the work is lost if it is left out of a publication like this. For example, there are data from over 250 sites. Assuming that the author visited the majority of these he would have developed a broad understanding of current land use conditions and potential conservation issues and their significance. The scientific view of these issues needs to be provided. If the ecologist, with extensive field knowledge and understanding, does not provide interpretation that leads to guidelines on issues of scientific importance, how can we expect managers to make the most appropriate decisions.

As far as the map itself is concerned, there is no indication that it shows 'pre-settlement' vegetation rather than 'present-day' vegetation (except by reference to the text summary) and the user could be forgiven for thinking that the Ipswich area was still completely covered with closed-forest, open-forests and woodlands, which it is not. It would have been most helpful to have present-day vegetation coverage shown as a hatching or in a small inset map. There is also space on the map sheet for a much more detailed legend to reduce frequent reference to the text.

Delving deeper into the map unit descriptions, it is unclear how these have been defined. The methods used in developing the classification and how the vegetation types, map units, tree species associations and site groups are related, are not clearly explained. Some of the botanical nomenclature is not current, e.g. *Eucalyptus propinqua* var. *major* has been generally regarded as *E. major* since Blakely (1934),(including *Flora of Australia* 1988), but I understand the difficulties that ecologists face in keeping up with ever-changing nomenclature.

Published printed maps, not just possible access to digitised data, are essential if appropriate knowledge on vegetation patterns and composition is to reach users such as land managers, local government authorities, conservationists, environmental consultants, educators and other interested persons. I urge potential users to purchase copies of this map. Though the information gathered has not been fully expressed, it provides very detailed data on the vegetation of the area. However, as an effective publication, the map and text need far better interpretation, and I urge users to inform the Queensland Department of Primary Industries that they want future maps in the series to be more informative and user-friendly. There would appear to be no reason why this cannot be achieved.

References

Blakely, W.F. (1934) *A key to the Eucalypts* (The Worker Trustees: Sydney).
Chippendale, G.M. (1988) *Eucalyptus* in *Flora of Australia.* Vol. 19 (A.G.P.S : Canberra).

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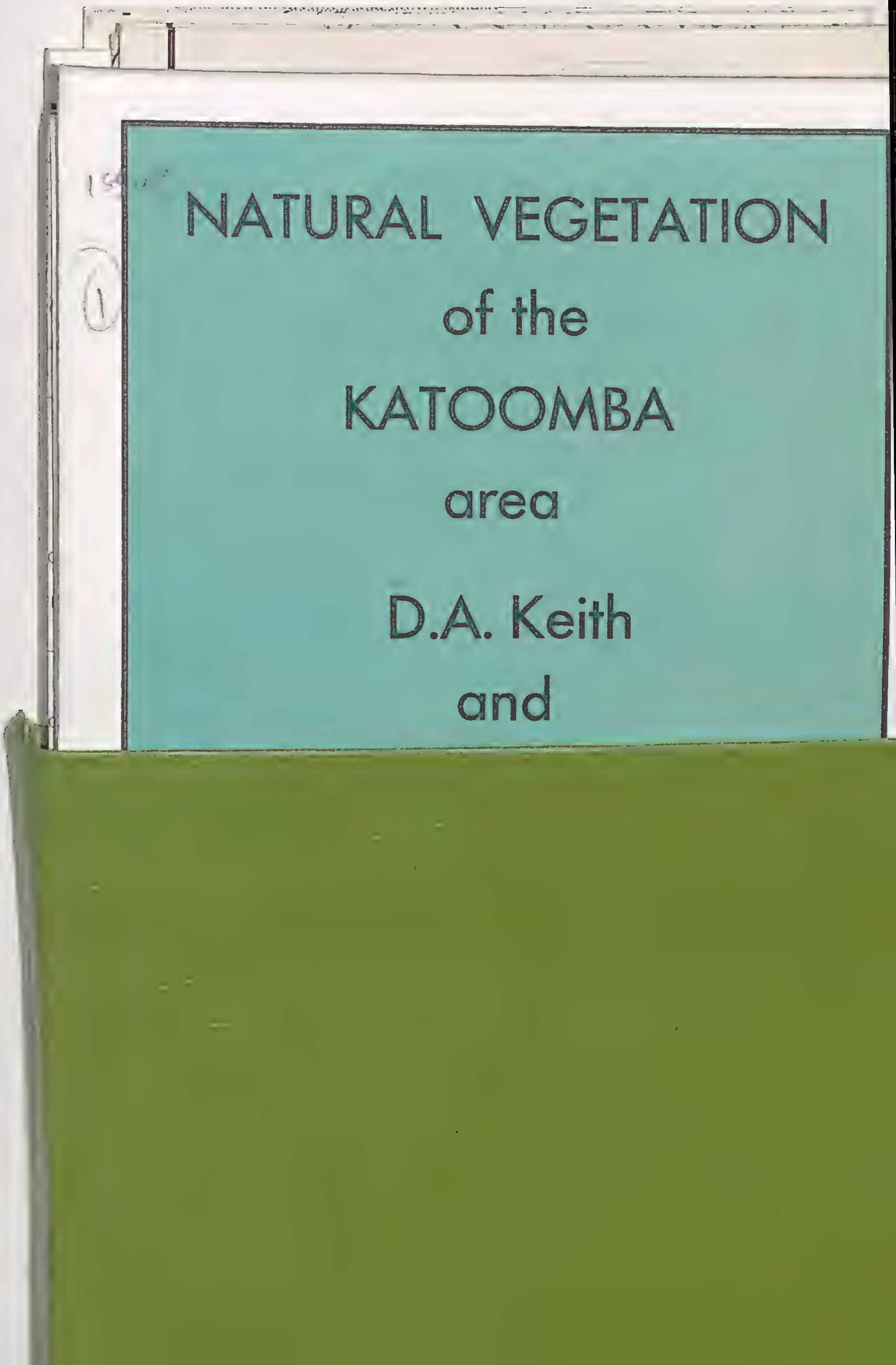
Royal Botanic Gardens
Sydney, Australia 2000

Royal Botanic Gardens Victoria
RBG00012613



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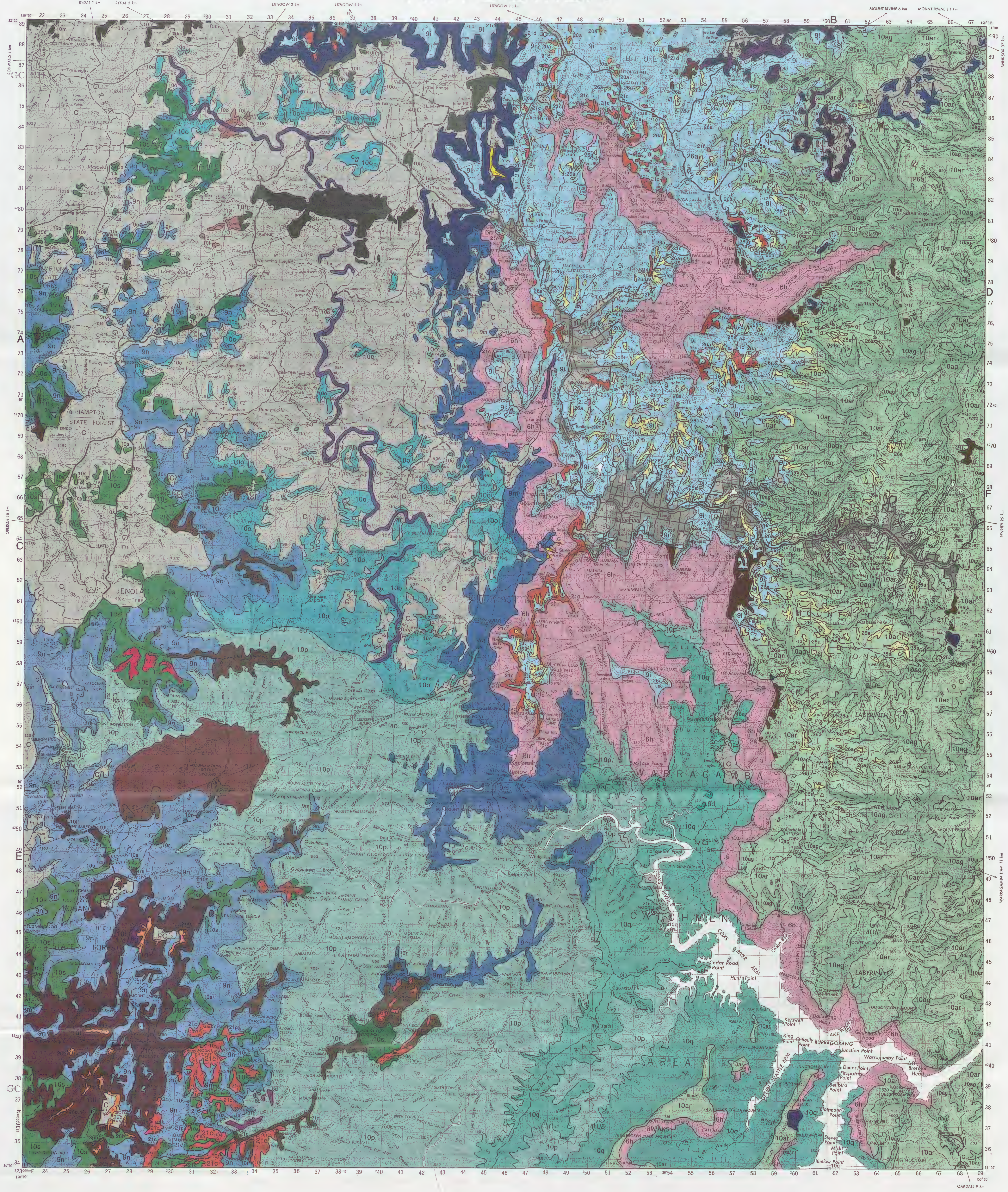
①

NATURAL VEGETATION
# of the
KATOOMBA
area

D.A. Keith
and

KATOOMBA

1:100 000 VEGETATION SERIES



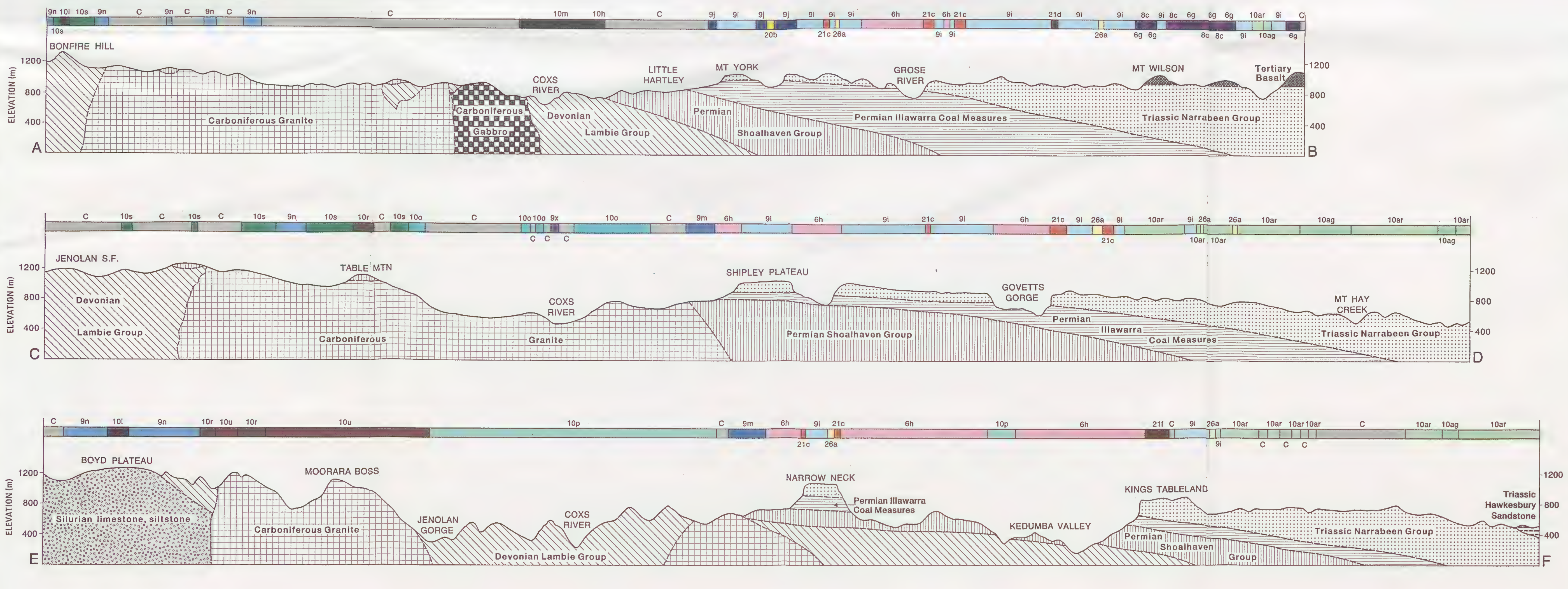
MAP UNIT DESCRIPTION

MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	ALTITUDE	HABITAT
'Glen Forest'					
	TALL OPEN-FOREST	*Eucalyptus deanei* *Syncarpia glomulifera*	Jurassic diatremes	<650m	Amphitheatre-shaped gullies
6d **'Camden White Gum Forest'**					
	TALL OPEN-FOREST	*Eucalyptus benthamii* *E. deanei*	Recent alluvium	<150m	Banks of Kedumba River
'Moist Basalt Cap Forest'					
	TALL OPEN-FOREST	*Eucalyptus viminalis* *E. blaxlandii* *E. fastigata*	Basalt caps	>800m	Ridges and slopes of residual basalt
6h **'Escarpment Complex'**					
	TALL OPEN-FOREST	*Eucalyptus deanei* *E. cypellocarpa* *Syncarpia glomulifera*	Illawarra Coal Measures	120-850m	Escarpment slopes
	OPEN-FOREST	*Angophora costata* ssp. *costata* *Eucalyptus piperita* ssp. *piperita* *E. punctata*	Shoalhaven Group	120-850m	Undulating country below escarpment slopes
	CLOSED-FOREST	*Ceratopetalum apetalum* *Doryphora sassafras*	Illawarra Coal Measures	120-850m	Sheltered gullies on escarpment slopes
'Montane Rainforest'					
	CLOSED-FOREST	*Ceratopetalum apetalum* *Doryphora sassafras* *Quintinia sieberi*	Illawarra Coal Measures, Tertiary basalt	600-1000m	Sheltered gullies on escarpment slopes. Also found on basalt caps
8d **'Kowmung Dry Rainforest'**					
	CLOSED-FOREST	*Toona australis* *Ehretia acuminata* *Brachychiton populneum*	Devonian Lambie Group	300-700m	Sheltered lower slopes in deeply Kowmung area
9a **'Shale Cap Forest'**					
	OPEN-FOREST	*Eucalyptus notabilis* *E. globoidea* *Syncarpia glomulifera*	Wianamatta Shale	<750m	Ridgetop, Berambing to Bilpin
9i **'Blue Mountains Sandstone Plateau Forest'**					
	OPEN-FOREST	*Eucalyptus sieberi* *E. piperita* ssp. *piperita*	Narrabeen Group	800-1150m	Dissected sandstone plateaux
'Montane Gully Forest'					
	OPEN-FOREST	*Eucalyptus fastigata* *E. cypellocarpa* *E. dalrympleana* ssp. *dalrympleana*	Narrabeen Group	850-1100m	Gorges and escarpment slopes
9m **'Megalong Forest'**					
	OPEN-FOREST	*Angophora costata* ssp. *costata* *Eucalyptus punctata* *E. sieberi*	Shoalhaven Group	400-750m	Undulating country below escarpment slopes
9n **'Montane Moist Forest'**					
	OPEN-FOREST	*Eucalyptus fastigata* *E. dalrympleana* ssp. *dalrympleana* *E. viminalis*	Lambie Group, Carboniferous granites	>700m	Steep slopes and moist sheltered gullies
9x **'River Oak Forest'**					
	OPEN-FOREST	*Casuarina cunninghamiana*	Alluvium	<800m	Along major watercourses
10ag **'Sydney Sandstone Complex'**					
	OPEN-FOREST	*Angophora costata* ssp. *costata* *Eucalyptus piperita* ssp. *piperita* *E. agglomerata*	Narrabeen Group, Hawkesbury Sandstone	<800m	Dissected plateau, in gullies
10ar **'Sydney Sandstone Complex'**					
	WOODLAND	*Eucalyptus gummifera* *E. sclerophylla* *E. oblonga*	Narrabeen Group, Hawkesbury Sandstone	<800m	Dissected plateau, on ridges
'Tablelands Grassy Woodland Complex'					
	WOODLAND	*Eucalyptus dives* *E. mannifera* ssp. *mannifera* *E. eugenioides*	Shoalhaven Group	>800m	Undulating to hilly country
	WOODLAND	*E. pauciflora* ssp. *pauciflora* *E. rubida*		>800m	Valleys with frost hollows
	WOODLAND	*Eucalyptus aggregata* *E. mannifera* ssp. *mannifera* *E. stellulata*		>800m	Poorly-drained depressions
'Snow Gum Woodland'					
	WOODLAND	*Eucalyptus pauciflora* ssp. *pauciflora* *E. dalrympleana* ssp. *dalrympleana*	Lambie Group, Carboniferous granites	>1100m	Undulating country on Great Dividing Range
	WOODLAND	*Eucalyptus pauciflora* ssp. *pauciflora* *E. rubida* *E. stellulata*		>1100m	Frost hollows
'Mount Walker Complex'					
	WOODLAND	*Eucalyptus macrorhyncha* *E. melliodora*	Devonian Lambie Group	>600m	Rugged country around Mt Walker and south of Hartley
10o **'Yellow Box Woodland'**					
	WOODLAND	*Eucalyptus melliodora* *E. viminalis*	Carboniferous granites	250-850m	Cox River valley

MAP UNIT DESCRIPTION

MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	ALTITUDE	HABITAT
10p **'Kowmung Wilderness Complex'**					
	WOODLAND	*Eucalyptus tereticornis* *E. melliodora*	Devonian Lambie Group	<900m	Dissected country of the lower Cox and Kowmung Rivers. Gullies and moist slopes
	WOODLAND	*Eucalyptus fibrosa* ssp. *fibrosa* *E. crebra* *E. eugenioides* *E. punctata*	Devonian Lambie Group	<900m	Dissected country of the lower Cox and Kowmung Rivers. Ridges and drier aspects
10q **'Burragorang Ironbark Woodland'**					
	WOODLAND	*Eucalyptus crebra* *E. eugenioides* *E. punctata* *E. fibrosa* ssp. *fibrosa*	Shoalhaven Group	<500m	Undulating country
	WOODLAND	*Eucalyptus sclerophylla* *Angophora bakeri* ssp. *bakeri*	Shoalhaven Group	<450m	Western aspect of ridges in Kedumba Valley
10r **'Residual Sandstone Woodland'**					
	WOODLAND	*Eucalyptus sieberi* *E. blaxlandii*	Shoalhaven Group	>900m	Rocky, high altitude ridges
10s **'Montane Woodland'**					
	WOODLAND	*Eucalyptus radiata* ssp. *radiata* *E. dalrympleana* ssp. *dalrympleana*	Lambie Group, Carboniferous granites, Shoalhaven Group	>900m	Gentle slopes, ridges and undulating country
	WOODLAND	*E. ovata* *E. stellulata*			Poorly-drained depressions
10t **'Mount Blaxland Complex'**					
	WOODLAND	*Eucalyptus sieberi* *E. pulverulenta*	Devonian metamorphic & igneous rocks	700-1000m	Mt. Blaxland, Wentworth's Sugarloaf
10u **'Jenolan Granite Woodland'**					
	WOODLAND	*Eucalyptus punctata* *E.* sp. nov. "MAHEK" *E. sieberi*	Carboniferous granites	300-1100m	Steep north-facing slopes
'Black Range Scrub'					
	OPEN-SCRUB	*Eucalyptus mannifera* ssp. *mannifera* *Leptospermum* sp. nov. "A" *L. myrtifolium* *Patersonia fragilis*	Devonian Lambie Group	1050-1150m	Soaks on southerly aspects of Black Range
20a **'Newnes Plateau Shrub Swamps'**					
	CLOSED-HEATH	*Leptospermum lanigerum* *Baeckea linifolia* *Grevillea acanthifolia* *Xyris ustulata*	Narrabeen Group	>1000m	Shrub-swamps in narrow headwater valleys
20b **'Coxs River Swamps'**					
	CLOSED-HEATH	*Leptospermum obovatum* *L. flavescens* *Grevillea acanthifolia*	Illawarra Coal Measures	>600m	Valleys and headwaters of creeks
21c **'Montane Heath'**					
	OPEN-HEATH	*Eucalyptus stricta* *Allocasuarina nana* *Leptospermum attenuatum* *Phyllota squarrosa* *Eriostemon obovalis*	Narrabeen Group	>850m	Exposed rock ridges on shallow sandy soils, often western aspects
	OPEN-HEATH	*Epacris reclinata* *Dracophyllum secundum* *Gleichenia rupestris*		>850m	Moist rock faces
21d **'Pagoda Rock Complex'**					
	OPEN-HEATH	*Allocasuarina nana* *Leptospermum arachnoides* *Lepidosperma viscidum*	Narrabeen Group	>750m	Exposed sites on rock outcrops with shallow soils. Associated with extensive rocky platforms and "pagoda" rock formations
	OPEN-SCRUB	*Eucalyptus* sp. nov. "MOKII"		>750m	
	WOODLAND	*Eucalypyus sieberi* *E. piperita* ssp. *piperita*		>750m	Small sheltered gullies between rocky knolls
'Lower Blue Mountains Heath'					
	OPEN-HEATH	*Eucalyptus stricta* *Allocasuarina nana* *Leptospermum attenuatum* *Phyllota phylicoides* *Eriostemon hispidulus*	Narrabeen Sandstone	<850m	Exposed rocky ridges, often on western aspects of escarpment tops
	OPEN-HEATH	*Epacris reclinata* *Dracophyllum secundum* *Gleichenia rupestris*		<850m	Moist rock
26a **'Blue Mountains Sedge Swamps'**					
	CLOSED-SEDGELAND	*Gymnoschoenus sphaerocephalus* *Lepidosperma limicola* *Xyris ustulata* *Baeckea linifolia*	Narrabeen Sandstone with peaty sand	<1000m	Headwater gullies or on hillsides
26b **'Boyd Plateau Bogs'**					
	CLOSED-SEDGELAND	*Carex appressa* *C. gaudichaudiana* *Juncus holoschoenus* ssp. *fockei* *Baeckea utilis*	Carboniferous granite with acid peats.	>1200m	Headwater gullies
	CLOSED-HEATH	*Leptospermum myrtifolium* *L. obovatum* *L. lanigerum*		>1200m	Headwater gullies
C	CLEARED:	Native vegetation has been largely removed for agricultural, industrial or urban development but remnant vegetation of varying sizes and condition may remain.			

Schematic profiles showing relationships between map units, geology and topography.



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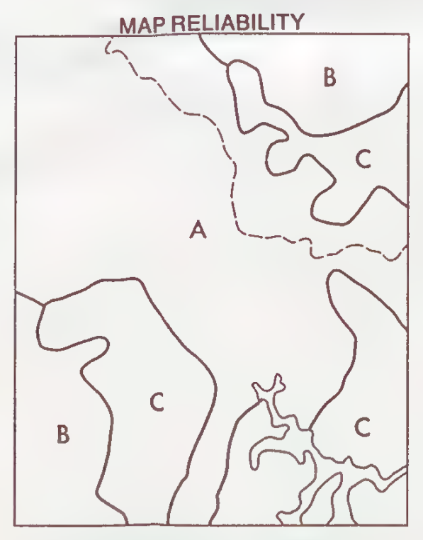
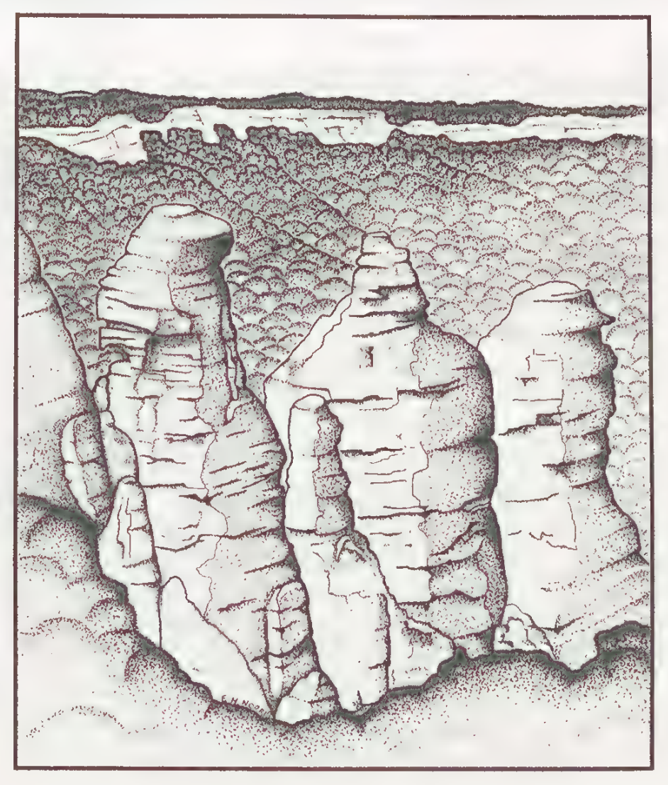


A Aerial photograph interpretation with extensive field reconnaissance.

B Aerial photograph interpretation with limited field reconnaissance.

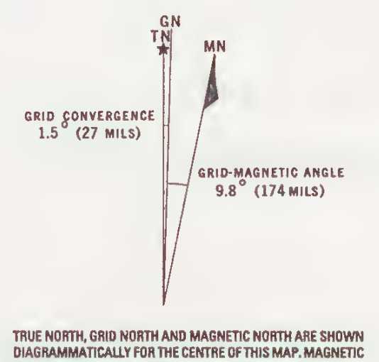
C Aerial photograph interpretation only.



INDEX TO ADJOINING MAPS

BATHURST 8831	WALLERAWANG 8931	ST ALBANS 9031
OBERON 8830	KATOOMBA 8930	PENRITH 9030
TARALGA 8829	BURRAGORANG 8929	WOLLONGONG 9029

THIS MAP IS PART OF SHEET
S1 56-5 SYDNEY
IN THE 1:250 000 SCALE SERIES



GN
TN
MN
GRID CONVERGENCE 1.5° (27 MILS)
GRID-MAGNETIC ANGLE 9.8° (174 MILS)

TRUE NORTH, GRID NORTH AND MAGNETIC NORTH ARE SHOWN DIAGRAMMATICALLY FOR THE CENTRE OF THIS MAP. MAGNETIC NORTH IS CORRECT FOR 1970 AND MOVES EASTERLY BY 0·1° IN ABOUT THREE YEARS.

Topographic base from Katoomba 8930, 1:100 000 Map Sheet,
Australian Surveying and Land Information Group, Department of Administrative Services.

ELEVATIONS IN METRES. CONTOUR INTERVAL 20 METRES

SCALE 1:100 000

Kilometres 2 0 2 4 6 8 10 Kilometres

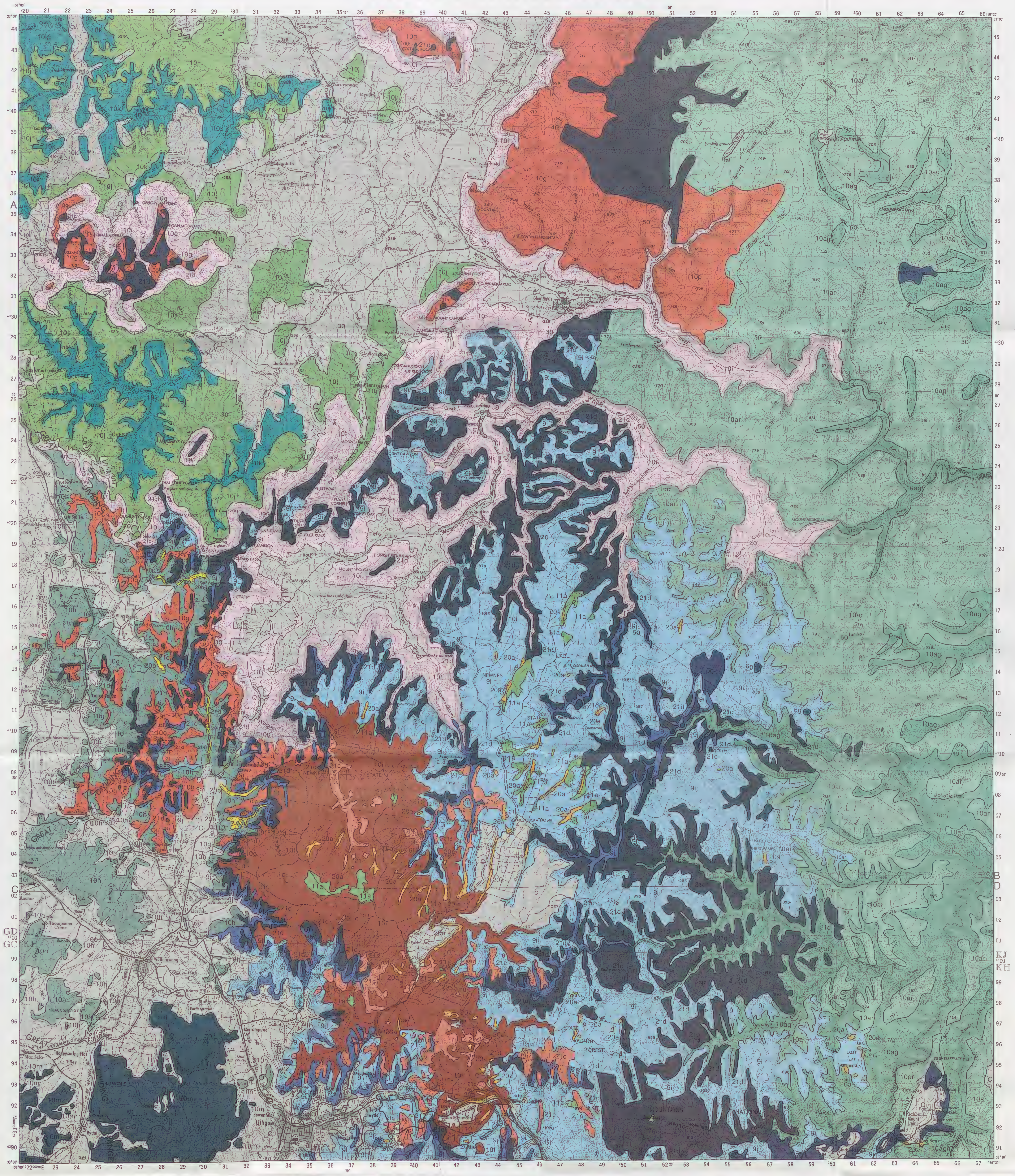
NATURAL VEGETATION of the KATOOMBA area

D.A. Keith
and
D.H. Benson

Compiled and prepared at the
NATIONAL HERBARIUM OF NEW SOUTH WALES,
ROYAL BOTANIC GARDENS, SYDNEY.
To accompany CUNNINGHAMIA VOLUME 2, NUMBER 1, 1988.
printed by CMA DEPARTMENT OF LANDS N.S.W.

WALLERAWANG

1:100 000 VEGETATION SERIES



MAP UNIT DESCRIPTION

MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	ALTITUDE	HABITAT
6g	**"Moist Basalt Cap Forest"**				
	TALL OPEN-FOREST	*Eucalyptus viminalis* *E. blaxlandii*	Tertiary Basalt	>800m	Isolated residual caps eg. Mt. Cameron
9i	**"Blue Mountains Sandstone Plateau Forest"**				
	OPEN-FOREST	*Eucalyptus sieberi* *E. piperita*	Narrabeen Group	800-1150m	Sandstone plateaus and ridges
9j	**"Montane Gully Forest"**				
	OPEN-FOREST	*Eucalyptus fastigata* *E. cypellocarpa* *E. dalrympleana*	Narrabeen Group	850-1100m	Gorges and sheltered gullies
10ag	**"Sydney Sandstone Gully Forest"**				
	OPEN-FOREST	*Angophora costata* *Eucalyptus piperita* *E. agglomerata*	Narrabeen Group Hawkesbury Sandstone	<800m	Valleys and lower slopes
10ar	**"Sydney Sandstone Ridgetop Woodland"**				
	WOODLAND	*Eucalyptus gummifera* *E. sclerophylla* *E. oblonga*	Narrabeen Group Hawkesbury Sandstone	<800m	Plateaus and ridges at lower altitudes
10f	**"Newnes Plateau Woodland"**				
	WOODLAND	*Eucalyptus sieberi* *E. oreades* *E. dives*	Narrabeen Group	>1050m	High altitude plateau of Newnes State Forest.
10g	**"Scribbly Gum-Stringybark Woodland"**				
	WOODLAND	*Eucalyptus rossii,* *E. oblonga*	Narrabeen Group	>800m	Sandstone plateaus and ridges with lower rainfall than 9i
10h	**"Tablelands Grassy Woodland Complex"**				
	WOODLAND	*Eucalyptus rossii,* *E. macrorhyncha,*	Permian Illawarra Group	>800m	Hilly country, dry aspects
	WOODLAND	*E. mannifera,* *E. dives*			Undulating to hilly country
	OPEN-FOREST	*E. dalrympleana*			Alluvium in valleys
	WOODLAND	*E. pauciflora* *E. rubida*			Valleys with frost hollows
10i	**"Talus-slope Woodland"**				
	WOODLAND	*Eucalyptus rossii* *E. macrorhyncha* *E. polyanthemos* *E. fibrosa*	Permian Illawarra Group	200-900m	Talus of major valleys, exposed sites
	OPEN-FOREST	*E. cypellocarpa,* *E. eugenioids,* *E. melliodora,* *E. melliodora*			Sheltered sites
10j	**"Capertee Valley Woodland"**				
	WOODLAND	*Eucalyptus melliodora,* *E. blakelyi,* *+/-E. albens,* *+/-E. crebra*	Permian Shoalhaven Group	300-700m	Possibly limestone influenced
	WOODLAND	*Eucalyptus fibrosa,* *E. crebra* *+/-E. rossii* *+/-E. oblonga*			Dissected plateaus

MAP UNIT DESCRIPTION

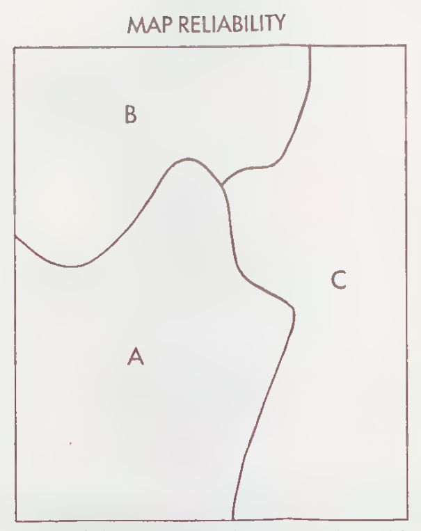
MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	ALTITUDE	HABITAT
10k	**"White Box Woodland"**				
	WOODLAND	*Eucalyptus albens,* *Brachychiton populneus*	Devonian shale, siltstone quartzite, tuff, limestone	400-600m	Gorges of Airly, Coco and Genowlan Creeks
	WOODLAND	*Angophora floribunda,* *Eucalyptus melliodora* *E. melliodora*			Alluvial/ colluvial soils, riverine
10m	**"Mount Walker Complex"**				
	WOODLAND	*Eucalyptus dives,* *E. mannifera,* *E. bridgesiana* *E. rossii*	Devonian Lambie Group; quartzites, sandstones, siltstones claystones	>600m	Rugged country around Mt Walker
10n	**"Dry Basalt Cap Woodland"**				
	WOODLAND	*E. polyanthemos* *E. macrorhyncha*	Tertiary Basalt	>1000m	Residual caps on sandstone mesas and plateaus.
11a	**"Open Mottled Gum Woodland"**				
	OPEN-WOODLAND	*Eucalyptus Mannifera,* *E. Dives* *E. pauciflora* *+/-E. radiata,*	Narrabeen Group	>900m	Poorly-drained creeks and shallow valleys, often surrounding shrub swamps
20a	**"Newnes Plateau Shrub Swamps"**				
	CLOSED-HEATH	*Baeckea linifolia,* *Grevillea acanthifolia,* *Leptospermum grandifolium*	Narrabeen Group alluvium	>1000m	Shrub-swamps in narrow headwater valleys
	SEDGELAND	*Gymnoschoenus sphaerocephalus,* *Xyris ustulata*			
20b	**"Cox River Swamps"**				
	CLOSED-HEATH	*Leptospermum obovatum* *L. continentale*	Alluvium	>600m	Valleys and headwaters of creeks
	SEDGELAND	*Carex spp.*			
21c	**"Montane Heath"**				
	OPEN-HEATH	*Allocasuarina nana* *Banksia ericifolia* *Leptospermum attenuatum* *Phyllota squarrosa*	Narrabeen Group	>850m	Exposed sites on shallow sandy soils
21d	**"Pagoda Rock Complex"**				
	OPEN-HEATH	*Allocasuarina nana* *Leptospermum arachnoides* *Lepidosperma viscidum*	Narrabeen Group		Exposed sites on rock out-crops with shallow soils.
	OPEN SCRUB	*Eucalyptus sp. nov MOKII*			Associated with extensive rocky platforms, and 'pagoda' rock formations.
	WOODLAND	*E. rossii,* *E. piperita*			Small sheltered gullies.
C	**Cleared**	Native vegetation has been largely removed for agricultural, industrial or urban development but remnant vegetation of varying sizes and condition may remain.			

Topographic base from Wallerawang 8931, 1:100 000 Map Sheet,
Australian Surveying & Land Information Group, Department of Administrative Services.
"Colour separated and printed by the Land Information Centre, NSW Department of Lands"
ELEVATIONS IN METRES. CONTOUR INTERVAL 20 METRES

SCALE 1:100 000

Kilometres 2 0 2 4 6 8 10 Kilometres

MAP RELIABILITY



- A Aerial photograph interpretation with extensive field reconnaissance.
- B Aerial photograph interpretation with limited field reconnaissance.
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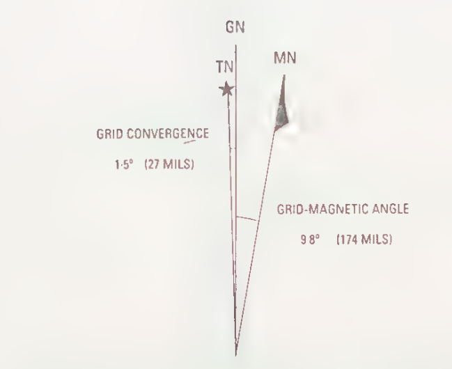

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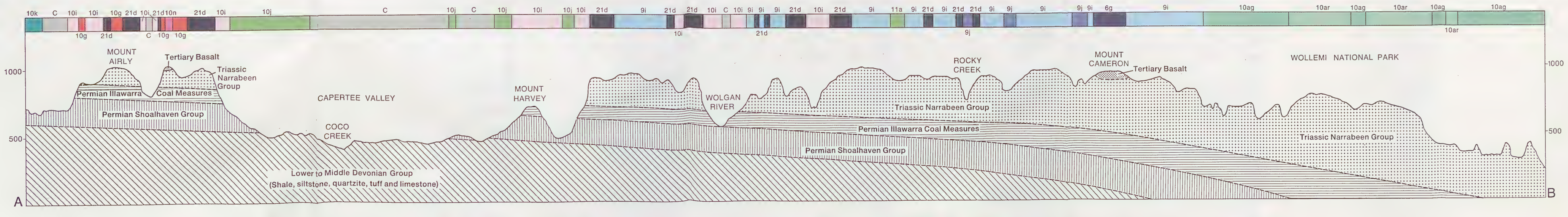
Eliza Thurston
CAPERTEE VALLEY
TAKEN FROM CROWN RIDGE SYDNEY ROAD 1868
Watercolour

Mitchell Library

Schematic profiles showing relationships between map units, geology and topography.



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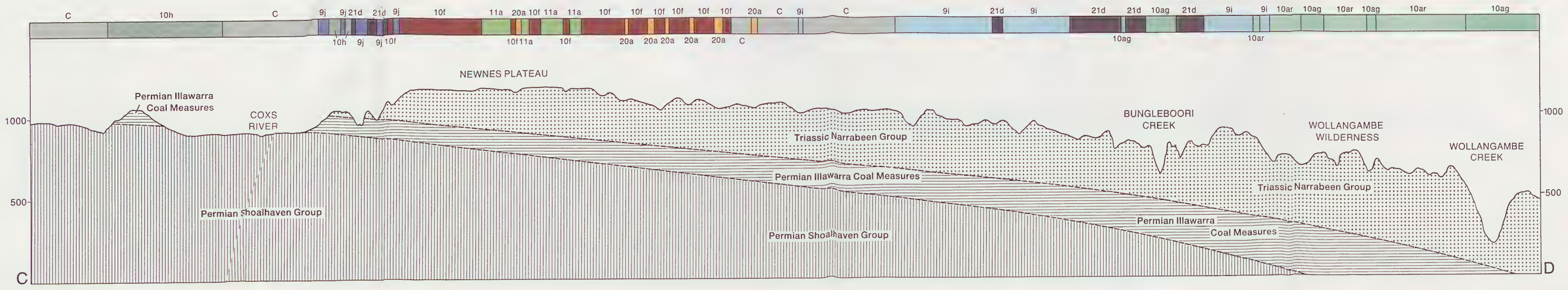
10g 21d C 10g 10g 10i 21d 9j 10ar
MOUNT AIRLY
Tertiary Basalt
Triassic Narrabeen Group
Permian Illawarra Coal Measures
Permian Shoalhaven Group
CAPERTEE VALLEY
COCO CREEK
MOUNT HARVEY
WOLGAN RIVER
ROCKY CREEK
MOUNT CAMERON
Tertiary Basalt
WOLLEMI NATIONAL PARK
Triassic Narrabeen Group
Permian Illawarra Coal Measures
Permian Shoalhaven Group
Triassic Narrabeen Group
Lower to Middle Devonian Group
(Shale, siltstone, quartzite, tuff and limestone)
ELEVATION (m)
1000
500
A
B



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10h 9j 9j 10f 10f 11a 10f 20a 20a 20a 20a 20a C 10ag 10ar
NEWNES PLATEAU
Permian Illawarra Coal Measures
COXS RIVER
BUNGLEBOORI CREEK
WOLLANGAMBE WILDERNESS
WOLLANGAMBE CREEK
Triassic Narrabeen Group
Permian Illawarra Coal Measures
Triassic Narrabeen Group
Permian Shoalhaven Group
Permian Illawarra Coal Measures
Permian Shoalhaven Group
ELEVATION (m)
1000
500
C
D

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(2)

NATURAL VEGETATION
# of the
WALLERAWANG
area

D.H. Benson
and
D.A. Keith

Detailed descriptions of the plant communities are given in CUNNINGHAMIA VOLUME 2, NUMBER 2, 1990

Compiled and prepared at the
NATIONAL HERBARIUM OF NEW SOUTH WALES,
ROYAL BOTANIC GARDENS, SYDNEY.

Understanding the ecology of our native plants.

NATIVE PLANT SPECIES OF THE WALLERAWANG AREA

This list was compiled from field work records for the Wallerawang map sheet by Doug Benson and David Keith, with additional records for the Newnes Plateau by Peter Hind and Keith Ingram, and for Glen Davis by Bob Coveny. It is not exhaustive and inevitably misses some of the less common or localised species. Some map units have been sampled more intensively than others.

Species names are those currently recognised at the National Herbarium of New South Wales, Royal Botanic Gardens, Sydney (for authorities see Jacobs, S.W.L. & Pickard, J. *Plants of New South Wales: a census of the cycads, conifers and angiosperms*. Government Printer, Sydney, 1981). Non-vascular species have not been included.

Map units

6g	Moist Basalt Cap Forest
9i	Blue Mountains Sandstone Plateau Forest
9j	Montane Gully Forest
10a	Sydney Sandstone Complex - includes both Sydney Sandstone Ridgetop Woodland (10ar) and Sydney Sandstone Gully Forest (10ag)
10f	Newnes Plateau Woodland
10g	Scribbly Gum-Stringybark Woodland
10h	Tablelands Grassy Woodland Complex
10i	Talus-slope Woodland
10j	Capertee Valley Woodland
10k	White Box Woodland
10m	Mount Walker Complex
10n	Dry Basalt Cap Woodland
11a	Open Mottled Gum Woodland
20a	Newnes Plateau Shrub Swamps
20b	Coxs River Swamps
21c	Montane Heath
21d	Pagoda Rock Complex

PTERIDOPHYTES

ADIANTACEAE	
Adiantum aethiopicum	10m
ASPIDIACEAE	
Lastreopsis acuminata	9j
Polystichum proliferum	6g, 10m
ASPLENIACEAE	
Asplenium bulbiferum	9j
A. flabellifolium	9j, 10m, 10n, 21d
A. flaccidum	9j
BLECHNACEAE	
Blechnum ambiguum	9j, 10i
B. cartilagineum	9j
B. minus	11a
B. nudum	9j, 10h, 10m, 20a
B. patersonii	9j
B. wattsii	9j
Doodia aspera	10i
CYATHEACEAE	
Cyathea australis	6g, 9j
DENNSTAEDTIACEAE	
Histiopteris incisa	9j
Pteridium esculentum	6g, 9i, 9j, 10a, 10f, 10h, 10i, 10k, 10m, 11a, 20a, 21d
DICKSONIACEAE	
Culcita dubia	9j, 10i, 21d
Dicksonia antarctica	9j
GLEICHENIACEAE	
Gleichenia dicarpa	20a
G. microphylla	10f
G. rupestris	9j, 10i
Sticherus flabellatus	9j, 10i
S. tener	9j
GRAMMITIDACEAE	
Grammitis billardieri	9j
HYMENOPHYLLACEAE	
Hymenophyllum cupressiforme	9j
Polyphlebium venosum	9j
LINDSAEACEAE	
Lindsaea linearis	10f, 11a, 21c, 21d
L. microphylla	9j
LYCOPODIACEAE	
Lycopodium deuterodensum	10f
L. laterale	10i, 20a
OPHIOGLOSSACEAE	
Ophioglossum lusitanicum subsp. coriaceum	21d
OSMUNDACEAE	
Leptopteris fraseri	9j
Todea barbara	9j, 10i, 20a, 20b
POLYPODIACEAE	
Microsorum diversifolium	9j
M. scandens	9j
Pyrrosia rupestris	9j
PTERIDACEAE	
Pteris tremula	9j
SCHIZAEACEAE	
Schizaea bifida	10f
SINOPTERIDACEAE	
Cheilanthes sieberi	10h, 10j, 10m, 10n, 21d
Pellaea falcata	10i
TMESIPTERIDACEAE	
Tmesipteris truncata	9j

GYMNOSPERMS

CUPRESSACEAE	
Callitris endlicheri	10i, 10j, 21d
C. muelleri	10g, 21d
C. rhomboidea	21d
ZAMIACEAE	
Macrozamia communis	10j

DICOTYLEDONS

APIACEAE	
Actinotus helianthi	21c, 21d
A. forsythii	21d
Centella asiatica	6g, 9j, 20a
Daucus glochidiatus	10k
Hydrocotyle acutiloba	10m
H. laxiflora	6g, 10h, 10i, 10k, 10n
H. peduncularis	20a
Platysace ericoides	10a, 10f, 10g
P. lanceolata	9i, 9j, 10f, 10g, 10m, 21c, 21d
P. linearifolia	9i, 10a, 10f, 10h, 21c, 21d
Trachymene incisa	10i
Xanthosia atkinsoniana	10a
X. dissecta	20a
X. pilosa	9i, 9j, 10a, 10f, 21d
ARALIACEAE	
Astrotricha floccosa	10a
A. longifolia	10f
Polyscias sambucifolia	6g, 9j, 10a, 10f,
ASCLEPIADACEAE	
Tylophora barbata	6g, 10a
ASTERACEAE	
Arrhenechthites mixta	9j, 10f
Brachycome aculeata	10f
B. graminea	20a
B. rigida	10m
B. scapiformis	10h
Calomeria amaranthoides	9j
Calotis scapigera	10h
C. lappulacea	10i, 10k
Cassinia aculeata	10h, 21c
C. arcuata	9i, 9j, 10h, 21d
C. aureonitens	9j
C. cunninghamii	9j, 10a
C. denticulata	9j
C. uncata	10n
Celmisia longifolia	20a
Centipeda minima	10h
Cymbonotus preissianus	10h
Gnaphalium sphaericum	10g, 10h
Helichrysum apiculatum	10h, 10m
H. diosmifolium	10f, 21d
H. leucopsideum	10f
H. rutidolepis	10h, 10m
H. scorpioides	9j, 10f, 10g, 10h, 10m, 11a, 21c
Helipterum albicans subsp. albicans	10f, 10h
subsp. var. graminifolium	21d
Lagenifera sp. A var. A	10g
L. sp. A var. B	20a, 20b
Leptorhynchos squamatus	10h
Olearia erubescens	10h
O. microphylla	10a
O. myrsinoides	10f
O. phlogopappa	10f
O. quercifolia	20a
Podolepis jaceoides	10i
Pseudognaphalium luteo-album	10g
Senecio hispidus var. dissectus	10g, 10m
S. lautus	10k
S. quadridentatus	10f, 10h
S. velleoides	9j
S. diaschides	10j, 10m
Sigesbeckia orientalis	10k
Vittadinia triloba	10f
BAUERACEAE	
Bauera rubioides subsp. rubioides	20a
BIGNONIACEAE	
Pandorea pandorana	9j
BORAGINACEAE	
Cynoglossum suaveolens	10i
Myosotis sp.	10n
BRASSICACEAE	
Rorippa dictyosperma	9j
BRUNONIACEAE	
Brunonia australis	10f
CAMPANULACEAE	
Wahlenbergia communis	6g, 10j
W. gracilis	10f, 10m
W. stricta	10f, 10h, 10i, 10k, 10m
CARYOPHYLLACEAE	
Scleranthus biflorus	9j, 10h
Stellaria flaccida	9j
S. pungens	6g, 9i, 9j, 10g, 10h, 10i, 10m, 10n
CASUARINACEAE	
Allocasuarina distyla	21d
A. littoralis	9i, 9j, 10g, 10i
A. nana	21c, 21d
A. verticillata	10j
Casuarina cunninghamiana	10i, 10j
CELASTRACEAE	
Apatophyllum constablei	10i
Maytenus silvestris	10a
CHENOPODIACEAE	
Chenopodium pumilio	10g
Einadia hastata	10k, 10n
CLUSIACEAE	
Hypericum gramineum	10h, 10i, 10j, 10m
H. japonicum	10h
CONVOLVULACEAE	
Dichondra repens	6g, 10h, 10i, 10j, 10k, 10m, 10n
Polymeria calycina	10g
CRASSULACEAE	
Crassula sieberiana	10h, 10i, 10n
CUNONIACEAE	
Callicoma serratifolia	9j
Ceratopetalum apetalum	9j
C. gummiferum	9i, 10a
DILLENIACEAE	
Hibbertia acicularis	10a, 21c
H. cistiflora	10f
H. dentata	10a
H. diffusa	10i, 10j
H. empetrifolia	10a
H. linearis var. obtusifolia	8a, 9i, 9j, 10f, 10g, 10h, 10m
H. pedunculata	6g, 9i
H. serpyllifolia	9i, 21c
DROSERACEAE	
Drosera binata	20a
D. peltata	10f, 21c
D. spathulata	20a
ELAEOCARPACEAE	
Elaeocarpus holopetalus	9j
E. reticulatus	9j, 10i
EPACRIDACEAE	
Acrotriche aggregata	9j, 10f, 21d
A. serrulata	10j
Astroloma humifusum	10g, 10h, 10i, 10j
Brachyloma daphnoides	9i, 10a, 10h, 10m, 21c, 21d
Dracophyllum secundum	10a
Epacris crassifolia	21d
E. longiflora	21c
E. microphylla	10f, 11a, 21c, 21d
E. obtusifolia	21c
E. paludosa	20a, 20b, 21c, 21d
E. pulchella	9i, 9j, 10a, 10f, 21c
E. purpurascens var. onosmiflora	10f
E. reclinata	21c, 21d
Leucopogon lanceolatus	9i, 9j, 10a, 11a, 10g, 10i, 10m
L. microphyllus	21d
L. muticus	9i, 10a, 10f, 10g, 10h, 10i, 21d
L. setiger	10g, 10i, 21d
L. virgatus	10h, 10m
Lissanthe strigosa	10h, 10i, 10m
Melichrus urceolatus	10i, 10j, 10n
Monotoca scoparia	8a, 9i, 9j, 10a, 10f, 10g, 10h, 10m, 21c, 21d
Rupicola sp. 1	10i
Sprengelia incarnata	20a
Styphelia triflora	10g
S. tubiflora	9i
ESCALLONIACEAE	
Quintinia sieberi	9j
EUPHORBIACEAE	
Amperea xiphoclada	9i, 9j, 10f, 10g, 21c, 21d
Breynia oblongifolia	10a, 10i
Micrantheum ericoides	10h
Phyllanthus hirtellus (thymoides)	10a
Poranthera ericifolia	10a
P. microphylla	9j, 10h, 10i, 10m, 21d
Pseudanthus divaricatissimus	21c, 21d
Ricinocarpos pinifolius	10i
FABACEAE	
Acacia asparagoides	9j
A. brownii	10h
A. buxifolia	8a, 9i, 9j, 10f, 10g, 10h, 10i, 21d
A. dawsonii	9i, 10g, 10h
A. dealbata	9j, 10f, 10h, 10m
A. decora	10i, 10k
A. dorothea	9i, 10f, 10g, 10h, 20a, 21c
A. echinula	10h
A. elata	10i
A. falciformis	6g, 9j, 10f, 10g, 10h, 10i, 10k, 10m, 21d
A. filicifolia	10a, 10i
A. gunnii	10g, 10h, 11a
A. hamiltoniana	9j, 21d
A. hakeoides	10j
A. implexa	9i, 10i, 10k, 10m
A. ixiophylla	10j
A. kybeanensis	9i, 10f, 21d
A. linifolia	10a, 10i
A. longifolia	10f
A. mearnsii	10f
A. melanoxylon	6g, 9j, 10m, 20b
A. myrtifolia	10a, 10h
A. obliquinervia	10i, 10m
A. obtusifolia	9i, 9j, 10a, 10i, 10m, 11a, 21d
A. paradoxa	10a, 10m
A. parvipinnula	10a
A. penninervis	10a
A. rubida	20a, 9i, 10g
A. saliciformis	10a
A. spectabilis	10j
A. suaveolens	10a, 21c, 21d
A. terminalis	9i, 9j, 10a, 10f, 10g, 10h, 10i, 21d
A. ulicifolia	9i, 10a, 10f, 10g, 10h, 10m, 21c
A. uncinata	10i
A. verniciflua	10i, 10n
Bossiaea buxifolia	10h, 10j, 10m
B. heterophylla	9i, 10a, 21d
B. lenticularis	20a
B. obcordata	9i, 10f, 10g
B. prostrata	10m
B. rhombifolia	10a
Cassia eremophila var. zygophylla	10j
Daviesia latifolia	9i, 10f, 10g, 11a, 20a
D. mimosoides	10h, 10i
D. ulicifolia	6g, 10a, 10i
D. virgata	8a, 10h, 10m
Desmodium brachypodum	10k
D. varians	6g, 10i, 10j, 10k, 10m, 10n
Dillwynia acicularis	10a, 10i, 21d
D. floribunda	10a
D. ramosissima	10g, 21c
D. retorta var. phylicoides	8a, 9i, 10a, 10f, 10g, 10h, 10m, 21d
D. stipulifera	20a
Glycine clandestina	6g, 10a, 10i, 10j, 10m
G. tabacina	9i, 10k
Gompholobium glabratum	10f
G. grandiflorum	10g, 21c, 21d
G. huegelii	9j, 10f, 10h, 21c
G. minus	10a
G. latifolium	9j, 10a, 21d
G. uncinatum	21d
Hardenbergia violacea	9i, 10a, 10h, 10i, 10j, 10m
Hovea lanceolata	10i
H. linearis	9i, 10a, 11a
H. longifolia	9j
H. pannosa	10i
Indigofera australis	10a, 10g, 10h, 10i, 10j, 10k, 10m, 10n
Lotus australis	10k
Mirbelia platyloboides	10f, 10g, 10h, 21c, 21d
Oxylobium ilicifolium	8a, 9i, 9j, 10a, 10h, 10m, 21d
Phyllota squarrosa	9i, 10a, 10f, 10g, 11a, 21c
Pultenaea divaricata	20a
P. ferruginea var. ferruginea	10a
P. flexilis	9j, 10a
P. incurvata	20a
P. microphylla	9j, 10h, 10j
P. scabra	9i, 9j, 10a
Sphaerolobium vimineum	20a
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Goodenia bellidifolia	10f, 10g, 10h, 10m, 11a, 20a, 21c
G. decurrens	9j, 21c, 21d
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G. ovata	9j, 10a, 10i
G. pinnatifida	10i
Scaevola hookeri	20b
Velleia montana	20a
HALORAGACEAE	
Gonocarpus micranthus	20a
G. tetragynus	10a, 10g, 10h, 10i, 10m, 21c
G. teucrioides	9j, 10a, 21d
Haloragis heterophylla	10h
Myriophyllum pedunculatum	20a
M. propinquum	20a
LAMIACEAE	
Ajuga australis	10h, 10i, 10k, 10n
Mentha diemenica	10h
M. satureioides	6g
Prostanthera cryptandroides	10i
P. granitica	21d
P. howelliae	10n
P. linearis	21d
P. ovalifolia	10i
P. rotundifolia	10i
Prunella vulgaris	10g
Scutellaria mollis	6g
LAURACEAE	
Cassytha pubescens	10a
LENTIBULARIACEAE	
Utricularia dichotoma	20a
LOBELIACEAE	
Isotoma axillaris	21c, 21d
I. fluviatilis subsp. borealis	20b
Lobelia gibbosa	10g
L. gracilis	21c
Pratia pedunculata	20b
LOGANIACEAE	
Logania albiflora	9j
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Amyema miquelii	10h
Atkinsonia ligustrina	9i
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Lythrum salicaria	20b
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Stephania japonica var. discolor	10i
MONIMIACEAE	
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M. montanum	10i
MYRSINACEAE	
Rapanea howittiana	10i
MYRTACEAE	
Angophora costata	10a
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Baeckea densifolia	21c
B. linifolia	11a, 20a, 20b
B. utilis	20a
Callistemon citrinus	20a
C. linearis	20a
C. paludosus	10m, 10n
C. pityoides (sieberi)	20a
Calytrix tetragona	9i, 10g, 21c, 21d
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E. beyeri	10a
E. blakelyi	10i, 10j
E. blaxlandii	10f, 11a
E. bridgesiana	10m
E. cannonii	10j
E. conica	10j
E. consideniana	10a, 10i
E. crebra	10i, 10j
E. cypellocarpa	9j, 10a, 10i
E. dalrympleana	9j, 10f, 10h, 10l, 10m, 11a
E. dawsonii	10i
E. dealbata	10k
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E. eugenioides	10i
E. eximia	10a
E. fastigata	9j, 10f, 10m, 21d
E. fibrosa	10j
E. goniocalyx	10j
E. gregsoniana	21c
E. ligustrina	9i, 10g
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E. melliodora	10i, 10j, 10k
E. microcarpa	10j
E. moorei	21c
E. multicaulis	21c
E. oreades	9j, 10f
E. oblonga (sparsifolia)	9i, 10a, 10g, 10h, 10j, 21d
E. parramattensis	10j
E. pauciflora	10f, 10h, 10l, 10m, 11a
E. piperita	9i, 9j, 10a, 10f, 10g, 10i, 21d
E. polyanthemos	10i, 10j, 10n
E. punctata	10a, 10g, 10i, 21d
E. radiata	9i, 9j, 10f, 11a, 10h
E. rossii	8a, 9i, 10f, 10g, 10h, 10i, 10j, 10m, 21d
E. rubida	9i, 10h
E. sclerophylla	9i, 10g, 10h, 21c
E. sideroxylon	10i, 10j
E. sieberi	9i, 9j, 10f, 10g, 10m, 11a, 21c, 21d
E. stellulata	10h
E. stricta	21c
E. tereticornis	10i, 10k
E. viminalis	6g, 10h, 10i, 10m
E. sp. aff. apiculata MOKII	21c
Kunzea capitata	21d
Leptospermum arachnoides	21d
L. blakelyi	21d
L. brevipes	10i
L. continentale	11a, 21c
L. grandifolium	20a
L. juniperinum	20a
L. lanigerum	11a, 20a, 20b
L. macrocarpum	10i
L. myrtifolium	10f, 10h, 11a
L. obovatum	11a, 20a, 20b
L. parvifolium	21d
L. polygalifolium (flavescens)	9i, 9j, 10a, 10g, 10h, 10i, 10m, 11a, 20b, 21c
L. rupicola	10i
L. sphaerocarpum	9i, 10a, 10h, 21c, 21d
L. trinervium (attenuatum)	9j, 10a, 10f, 10i, 21c, 21d
Micromyrtus sp. nov. aff. minutiflora	21c
Ochrosperma monticola	21c
Syncarpia glomulifera	10a
Tristania neriifolia	9j
Tristaniopsis collina	10a
OLACACEAE	
Olax stricta	21d
OLEACEAE	
Notelaea microcarpa	10k
ONAGRACEAE	
Epilobium billardieranum subsp. cinereum	10g, 10m
subsp. hydrophilum	20b
OXALIDACEAE	
Oxalis perennans (corniculata)	6g, 9j, 10h, 10j, 10k, 10n
PASSIFLORACEAE	
Passiflora cinnabarina	9j
PITTOSPORACEAE	
Billardiera procumbens	21c
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Bursaria longisepala	10a, 10j, 10n
B. spinosa	10i, 10k, 10m
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P. hispida	10h
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Comesperma defoliatum	10f
C. ericinum	10f
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B. marginata	9i, 9j, 10f, 21c
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G. arenaria	10n
G. johnsonii	10i
G. laurifolia	10f, 11a, 21c
G. mucronulata	10a, 10i
G. sericea	10a
Hakea dactyloides	9i, 10a, 10f, 10g, 10h, 10i, 10m, 11a, 21c, 21d
H. microcarpa	11a, 20a
H. propinqua	10i, 21c, 21d
H. salicifolia	9j
Isopogon anemonifolius	9i, 9j, 10f, 21c, 21d
I. anethifolius	10g, 21d
I. dawsonii	10i, 21d
I. prostratus	10f, 21c
Lambertia formosa	9i, 10g
Lomatia ilicifolia	10m
L. myricoides	10f, 10m
L. silaifolia	9i, 10a, 10f, 10g, 11a
Persoonia acerosa	21d
P. chamaepitys	9i, 10f, 21c
P. laurina	9i, 10f, 10g, 21c
P. levis	9i, 9j, 10a, 10f
P. linearis	9i, 9j, 10a, 10g, 10h, 10i, 10j, 10m, 21d
P. mollis	9j
P. myrtilloides	9i, 9j, 10f, 11a
P. oxycoccoides	10f, 11a
Petrophile canescens	9i, 10f, 10g, 11a, 21c
P. pulchella	10g, 21c
Stenocarpus salignus	10a
Symphionema montanum	9j, 10f
Telopea speciosissima	9j, 10f
Xylomelum pyriforme	10a
RANUNCULACEAE	
Clematis aristata	6g, 9j, 10h, 10i, 10m, 21d
C. glycinoides	6g, 10i, 10k
Ranunculus lappaceus	6g, 10h
RHAMNACEAE	
Cryptandra amara	21c, 21d
Pomaderris andromedifolia	9i, 10g, 21c, 21d
P. intermedia (sieberiana)	10a
P. lanigera	9j
P. ledifolia	21d
ROSACEAE	
Acaena novae-zelandiae	10h
A. ovina	10f, 10k
Rubus parvifolius	6g, 10m
R. rosifolius	9j
RUBIACEAE	
Asperula conferta	10k, 10m
A. scoparia	10h, 10k
Coprosma quadrifida	6g
Galium ciliare	10g, 10h
G. gaudichaudii	10h, 10i, 10j
G. propinquum	10h
Opercularia aspera	10m
O. hispida	10g, 10h, 10i, 10m
Pomax umbellata	9j, 10a, 10g, 10m, 21c, 21d
RUTACEAE	
Boronia anemonifolia	10f, 10g
B. anethifolia	9j
B. deanei	20a
B. microphylla	9i, 10f, 10g, 10h, 11a, 21c, 21d
B. nana var. hyssopifolia	10f
B. rigens	21d
Correa reflexa	10a, 10i
Eriostemon obovalis	21c, 21d
Phebalium lamprophyllum	21d
Philotheca salsolifolia	21c, 21d
Zieria aspalathoides	10i, 21d
Z. compacta	10i
Z. cytisoides	10i, 10m, 21d
SANTALACEAE	
Choretrum candollei	21d
C. pauciflorum	10f, 10g
Exocarpos cupressiformis	8a, 9i, 10g, 10m
E. strictus	9i, 9j, 10a, 10h, 10i
Leptomeria acida	9i, 9j, 10i
Omphacomeria acerba	9i, 10a, 10g, 10m
SAPINDACEAE	
Dodonaea boroniifolia	10g, 10i
D. multijuga	9j
D. triquetra	9j, 10a
D. viscosa subsp. angustissima	10g, 10i, 10j, 10m
SCROPHULARIACEAE	
Euphrasia collina subsp. speciosa	10h, 11a, 21c
Gratiola latifolia	20b
Parahebe derwentiana	10h
P. perfoliata	9j, 10h
P. sp. 1	10f
Veronica calycina	6g, 10h, 10k
V. plebeia	9j, 10f, 10i, 10n
SOLANACEAE	
Solanum prinophyllum	9j, 10k
S. stelligerum / cinereum	10n
STACKHOUSIACEAE	
Stackhousia monogyna	10h, 10m
S. viminea	10f
STERCULIACEAE	
Brachychiton populneus	10j, 10k
STYLIDIACEAE	
Stylidium graminifolium	8a, 9i, 10f, 10g, 10h, 10m, 11a, 20a
S. laricifolium	21d
S. lineare	10g, 21c, 21d
S. productum	10a, 21c, 21d
THYMELAEACEAE	
Pimelea curviflora subsp. C	10m
P. hirsuta	10i, 10k
P. linifolia	9i, 10a, 10f, 10g, 21d
TREMANDRACEAE	
Tetratheca rubioides	21c
T. rupicola	21d
T. thymifolia	10f
URTICACEAE	
Urtica incisa	10n
VERBENACEAE	
Chloanthes stoechadis	10a
VIOLACEAE	
Hybanthus monopetalus	10f
Viola betonicifolia	6g, 9j, 10f, 10h, 10n
V. hederacea	6g, 9j, 10a
V. sieberiana	9j, 20a
VITACEAE	
Cissus hypoglauca	10i
WINTERCEAE	
Tasmannia insipida	9j

MONOCOTYLEDONS

ANTHERICACEAE	
Allania endlicheri	21d
Arthropodium milleflorum	10h
Dichopogon fimbriatus	10m
Laxmannia gracilis	10f
Sowerbaea juncea	20a
Thysanotus juncifolius	21c
T. tuberosus	21c
Tricoryne elatior	10h, 10j
ASPHODELACEAE	
Bulbine bulbosa	10h
COLCHICACEAE	
Burchardia umbellata	20a
CYPERACEAE	
Carex appressa	10m
C. fascicularis	20b
C. gaudichaudiana	10h, 20b
Caustis flexuosa	9i, 10a, 10g, 21c, 21d
C. recurvata	21c, 21d
Cyperus gracilis	10i
Eleocharis sphacelata	20a
Gahnia aspera	10i, 20a
G. clarkei	10i
G. filifolia	11a, 21c
G. microstachya	9i
G. sieberiana	9i, 11a, 20a, 20b
G. subaequiglumis	11a
Gymnoschoenus sphaerocephalus	20a
Lepidosperma filiforme sens. lat.	21c, 21d
L. laterale	9i, 10a, 10i, 10k, 11a, 21c, 21d
L. lineare sens. lat.	10a, 10g, 21c
L. tortuosum	10f, 21c
L. viscosum	21d
Ptilanthelium deustum	9i, 21c
Schoenus apogon	10m
S. ericetorum	21c
S. melanostachys	10i
S. moorei	21c
S. villosus	21c
ERIOCAULACEAE	
Eriocaulon scariosum	20b
HAEMODORACEAE	
Haemodorum planifolium	10a, 10g, 21c, 21d
HYPOXIDACEAE	
Hypoxis hygrometrica	10f, 10h
IRIDACEAE	
Libertia paniculata	9j
Patersonia fragilis	20a
P. glabrata	9i, 9j, 10a, 10f, 10g, 21d
P. longifolia	20a
P. sericea	8a, 10a, 10f, 10g, 10h, 10m, 21c, 21d
JUNCACEAE	
Juncus australis	10h
J. continuus	10h, 20a, 20b
J. gregiflorus	20a
J. holoschoenus	10g
J. planifolius	20a
Luzula meridionalis	20a
L. ovata	10m, 20a
LOMANDRACEAE	
Lomandra confertifolia subsp. pallida	10i
L. cylindrica	10f
L. filiformis subsp. coriacea	10a, 10f, 10h, 11a
L. glauca	8a, 9i, 9j, 10a, 10f, 10g, 10h, 10j, 10k, 10m, 11a, 21c, 21d
L. gracilis	10a, 10g, 10h, 21d
L. longifolia	6g, 9j, 10a, 10f, 10h, 10i, 10k, 10m, 10n, 11a, 20b, 21c
L. montana	9j
L. multiflora	10f, 10h, 10j, 10k
L. obliqua	9i, 10a
ORCHIDACEAE	
Acianthus sp.	10a
Adenochilus nortonii	9j
Caladenia carnea	10f
C. dimorpha	10f
Calochilus paludosus	10f, 21c
C. robertsonii	10f, 21c
Chiloglottis reflexa	9j, 10f
Cryptostylis subulata	10g, 21c, 21d
Dendrobium speciosum	9j
D. striolatum	9j
D. teretifolium sens lat.	9j
Dipodium punctatum	9j, 10i
Diuris maculata	10f, 10h
D. sulphurea	10f, 10h
Eriochilus cucullatus	10a, 10f, 20a, 21c
Genoplesium fimbriatum	21c
G. morrisii	21c
G. nudiscapum (densum)	21c
G. sagittiferum	21c
Liparis reflexa	9j
Microtis uniflora	10h
Orthoceras strictum	10f, 21c, 21d
Prasophyllum elatum	21c
Pterostylis coccinea	9j
P. daintreana	21d
P. decurva	10f
P. longifolia	10a
P. nutans	10a
P. parviflora	11a, 20a, 21c, 21d
Sarcochilus falcatus	9j
Spiranthes sinensis	20a, 20b
Thelymitra circumsepta	11a
T. cyanea	20a
T. ixioides	
T. pauciflora	
T. rubra	
PHILESIACEAE	
Eustrephus latifolius	6g
Geitonoplesium cymosum	6g, 10i
PHORMIACEAE	
Dianella caerulea	9j, 10a
D. longifolia (laevis)	10a, 10i
Dianella revoluta	8a, 10a, 10f, 10g, 10i, 10j, 10k, 10m, 10n, 11a, 21c, 21d
D. prunina	9i
Stypandra glauca	9j, 10a, 10m, 21c, 21d
Thelionema (Stypandra) caespitosa	21c, 21d
POACEAE	
Agropyron scabrum var. scabrum	10i, 10m
Agrostis avenacea	10g, 10h, 10m, 20b
Amphipogon strictus	21c
Aristida benthamii	10h
A. ramosa	10k
A. vagans	10h, 10i, 10k
Bothriochloa macra	10i
Chionochloa pallida	9i, 10g, 10h, 10m
Chloris truncata	10i
C. ventricosa	10i
Cymbopogon refractus	10i, 10k
Danthonia laevis	10h
D. ? longifolia	21d
D. tenuior	10m
Deyeuxia gunniana	20a
Dichanthium sericeum	10k
Dichelachne micrantha	10h, 10i, 10j, 10m
D. rara	10g, 10h, 10i, 10m
Digitaria brownii	10i
D. parviflora	10i
Dimorphochloa rigida	10i
Echinopogon caespitosis	10h, 10m, 10n
E. ovatus	6g, 10g, 10h, 10i, 10j, 10k, 10m
Entolasia stricta	9j, 10a, 10m
Eragrostis brownii	10i
Imperata cylindrica var. major	10i
Microlaena stipoides	10f
Notochloe microdon	20a
Oplismenus imbecillus	10i
Poa labillardieri	10h, 10m, 11a
P. sieberiana	10h, 10k, 10m
Sorghum leiocladum	10i
Stipa pubescens	10a
S. rudis	10m
Tetrarrhena juncea	10a
Themeda australis	10g, 10h, 10i, 10k, 10m
Triodia irritans var. laxispicata	10k
RESTIONACEAE	
Empodisma minus	11a, 20a, 20b
Lepyrodia anarthria	20a
L. gracilis	20a
L. scariosa	10f, 11a, 20a, 21c
Restio australis	11a, 20b, 21c
SMILACACEAE	
Smilax glyciphylla	10a
XANTHORROEACEAE	
Xanthorrhoea arborea	10a
X. glauca subsp. angustifolia	10k
X. resinosa subsp. resinosa	10f, 11a
XYRIDACEAE	
Xyris gracilis subsp. gracilis	10f, 20a, 21c
X. ustulata	20a

ANA BRANCH – MILDURA

1: 250 000 VEGETATION SERIES

20 SEP 1991

1SSUP
13

Natural Vegetation

of the

ANA BRANCH – MILDURA
New South Wales

1:250 000 Map Sheet

Marilyn D. Fox

Descriptions of the plant communities are given in Cunninghamia 2(3) 1991

Compiled and prepared at the
National Herbarium of New South Wales
Royal Botanic Gardens Sydney

Understanding the ecology of our native plants

LIFE FORM	FOLIAGE COVER CLASSES		
	30–70%	10–30%	<10%
Medium trees 10–30 m	M3	M2	
Tall shrubs >2 m	S3	S2	
Low shrubs <2 m		Z2	Z1
Tussock grass & gramminoids	G3		
Other herbaceous plants		F2	

UPPER STRATUM SYMBOLS AND CODES

Code letter	Life form	Genus, family or group
c	Tree/shrub	*Casuarina*
e	Tree/shrub	*Eucalyptus*
k	Tree/shrub	Chenopodiaceae
g	Herb	Graminoids
k	Herb	Chenopodiaceae
y	Herb	Other grasses

LOWER STRATUM CODE

Code letter	Life form of lower stratum
S	Tall shrub >2 m
Z	Low shrub <2 m
H	Hummock Grass *Triodia irritans*
F	Other herbaceous plants including small chenopods

MAP UNIT DESCRIPTIONS

Pattern	No.	Code	Structure	Main species	Dominant plant community
▨	1	eM3F	Open-forest	*Eucalyptus camaldulensis*	Riverine Forest
	2	eM2S	Low open-woodland	*Eucalyptus largiflorens* *Atriplex nummularia*	Black Box Woodland
⁘	3	eS2H	Tall shrubland	*Eucalyptus socialis* *E. dumosa*	Dune Mallee
	4	cS2Z	Tall shrubland	*Casuarina pauper* *Alectryon oleifolius* subsp. *canescens*	Arid Shrubland
	5	eS2H/ cS2Z	Tall shrubland	Mosaic of 3 with 4	Arid Shrubland
	6	cS2Z/ eS2H	Tall shrubland	Mosaic of 4 with 3	Arid Shrubland
	7	cS2Z/ eS2H/ kZ2F	Tall shrubland	Mosaic of 4, 3 & 8	Arid Shrubland
▤	8	kZ2F	Low shrubland	*Maireana pyramidata* *Rhagodia spinescens*	Black Bluebush
	9	kZ2F	Low shrubland	*Maireana sedifolia* *Erodium* spp.	Bluebush
	10	kZ2F	Low shrubland	*Maireana pyramidata* *Atriplex* spp.	Lunette Shrubland
	11	kZ1F	Low open-shrubland	*Atriplex vesicaria* *Sclerostegia tenuis*	Bladder Saltbush
	12	kZ1F	Low open-shrubland	*Sclerostegia tenuis* *Atriplex* spp.	Pigface-Samphire
⁘	13	yG3F	Grassland	*Eragrostis australasica*	Canegrass Swamp
	14	gG3F	Sedgeland	*Eleocharis pallens*	Sedge Swamp
	15	kF2F	Open-herbland	*Disphyma clavellatum* *Sclerostegia tenuis*	Saltpan, Lakebed
Plant communities too small to be shown as separate map units.		eS2H	Tall shrubland	*Eucalyptus oleosa*	Sand Plain Mallee
		eS2H	Tall shrubland	*Eucalyptus gracilis*	Swale Mallee
		pM2S	Open-woodland	*Callitris glaucophylla*	Mixed Woodland
		wS3F	Tall shrubland	*Acacia victoriae*	Acacia Shrubland
		xS4F	Closed shrubland	*Muehlenbeckia cunninghamii*	Lignum Swamp
		kS3F	Tall shrubland	*Atriplex nummularia*	Old Man Saltbush

Map units show original vegetation cover before European settlement, as interpreted from aerial photography and field survey. Present vegetation has been affected by widespread grazing and localised clearing.

KEY TO ADJOINING MAPS

OLARY SI54-2	MENINDEE SI54-3	MANARA SI54-4
CHOWILLA SI54-6	**ANA BRANCH SI54-7**	POONCARIE SI54-8
RENMARK SI54-10	**MILDURA SI54-11**	BALRANALD SI54-12
PINNAROO SI54-14	OUYEN SI54-15	SWAN HILL SI-54-16

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PLANT COMMUNITIES OF THE
ANA BRANCH – MILDURA
1:250 000 MAP SHEET

Major plant communities

1. Riverine Forest

Map units: 1 (2)
Code: eM3F
Structural formation: Open-forest
Height: 25–40 m
Cover: 30–70%
Dominant species: *Eucalyptus camaldulensis* on levees: *E. largiflorens* on flats and along smaller streams.
Understorey species: *Acacia stenophylla, Chenopodium nitrariaceum, Melaleuca lanceolata.*
Ground layer: Mix of herbaceous species, many exotics
Species richness: (0.1 ha) 23.4 ± 4.1 (n=5)
Landform: River levees and flats between braided streams.
Habitat (photopattern): Often concentric linear photopatterns with oxbows
Soil: Heavy grey alluvium
Degradation/regeneration: Subject to frequent and prolonged flooding, major regeneration occurs as floods subside leading to 'wheatfield' regeneration of extremely dense seedling growth which gradually thin out as plants grow. Very fine stands of Riverine Forest occur along the upper reaches of the Anabranch and along the Murray River. Elsewhere they usually form a narrow band following the major streams.

2. Black Box Woodland

Map units: 2 (11, 12, 15)
Code: eM2S
Structural formation: Low open-woodland
Height:10–20 m
Cover: 10–30% (Basal area 0.5 m^2ha^{-1})
Dominant species: *Eucalyptus largiflorens*
Understorey species: *Atriplex nummularia, Chenopodium nitrariaceum.*
Ground layer: *Osteocarpum acropterum* var. *deminutum, Boerhavia diffusa, Chamaesyce drummondii, Scleroblitum atriplicinum*
Species richness: (0.1 ha) 36.6 ± 3.0 (n=7)
Landform: Floodplains beyond major rivers and dry lake margins
Habitat (photopattern): Along creek lines and less dense than Riverine Forest
Soil: Heavy grey clay
Degradation/regeneration: Subject to periodic inundation, major regeneration occurs as floods subside. Most stands contain trees of similar size (age) and may represent past establishment patterns. The Black Box Woodlands are prime grazing country and the understorey is affected by this land use. In particular much of the previously extensive *Atriplex nummularia* stands that formed a shrub layer under and between the Black Box trees have now been lost.

3. Dune Mallee

Map units: 3 (5, 6, 7)
Code: eS2H
Structural formation: Tall shrubland
Height: 2–10 m (function of time since fire)
Cover: 10–30% (Basal area 5m^2 ha^{-1})
Dominant species: *Eucalyptus socialis, E. costata, E. dumosa*
Understorey species: *Triodia irritans, Beyeria opaca, Podolepis capillaris, Chenopodium curvispicatum, Stipa nitida, Enchylaena tomentosa*
Species richness: (0.1 ha) 25.4 ± 0.8 (n= 5)
Landform: Longitudinal east-west dunes up to 10 m in height
Habitat (photopattern): Forms prominent small-grained photopattern
Soil: Calcareous red sand overlying grey clay
Degradation/regeneration: The dunes may become active with a wind-blown sandy surface if highly disturbed. Whereas the mallee eucalypts can resprout from lignotubers, *Triodia* is killed and new plants germinate soon after fire. Seedling eucalypts were rarely noted. Some areas of mallee have been cleared in the past.

4. Arid Shrubland, Belah-Rosewood

Map units: 4 (5, 6, 7)
Code: cS2Z
Structural formation: Tall shrubland
Height: 8–12 m
Cover:10–30% (Basal area 2.5 m^2ha^{-1})
Dominant species: *Casuarina pauper, Alectryon oleifolius* subsp. *canescens.*
Understorey species: *Maireana pyramidata, Olearia pimeleoides, Enchylaena tomentosa, Sclerolaena* spp., *Aristida contorta.*
Species richness: (0.1 ha) 39.7 ± 4.6 (n= 6)
Landform: Raised areas of highly calcareous heavy soils with calcrete fragments
Habitat (photopattern): No dunes apparent and uniform mottled photopattern
Soil: Fine red sandy loam with calcrete nodules
Degradation/regeneration: Preferentially cleared because of its slightly better soil and because the dominant species do not resprout as readily as mallee does.The dominant species form clumps and this creates a mosaic pattern. *Alectryon* flowers irregularly and no seedlings were observed. Root suckers develop around parent plants but are highly palatable to sheep and rabbits and are kept grazed down.

5. Arid Shrubland (mosaic of map unit 3 with 4)

Code: eS2H/cS2Z
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Dune Mallee (3) with Belah-Rosewood (4)
Habitat (photopattern): At least 70% of the area is dunefield but widely spaced with 4 in swales

6. Arid Shrubland (mosaic of map unit 4 with 3)

Code: cS2Z/eS2H
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Belah-Rosewood (4) with Dune Mallee (3)
Habitat (photopattern): Finer grained photopattern than 5, predominately 4, may have some dunes with mallee but too small to map

7. Arid Shrubland (mosaic of map units 4, 3 & 8)

Code: cS2Z/eS2H/kZ2F
Height: 8–12 m
Cover: 10–30%
Dominant species: Mosaic of Belah-Rosewood (4) with Dune Mallee (3) and Black Bluebush (8)
Habitat (photopattern): Quite irregular, more patchy than 4 and with occasional open patches (8), each component too small to map separately

8. Black Bluebush

Map units: 8 (9, 10)
Code: kZ2F
Structural formation: Low shrubland
Height: 1–2 m
Cover: 10–30 %
Dominant species: *Maireana pyramidata, Rhagodia spinescens*
Understorey species: *Sclerolaena* spp., *Osteocarpum acropterum* var. *deminutum, Atriplex* spp.
Species richness: 35.4 ± 2.7 (n= 9)
Landform: Clay plain
Habitat (photopattern): Some scattered clumps of 4
Soil: Calcareous red loamy sand, red-brown loam, consistently with calcretions in top 40 cm
Degradation/regeneration: Under grazing no regeneration occurs. Sheep browse these perennial shrubs but goats and rabbits are more damaging, often ring-barking the main stems and excavating and eating the roots. Degraded areas may be invaded by *Nitraria billardieri.*

9. Bluebush, Pearl Bluebush

Map unit: 9
Code: kZ2F
Structural formation: Low shrubland
Height: 1–2 m
Cover: 10–30 %
Dominant species: *Maireana sedifolia*
Understorey species: *Erodium* spp., *Tetragonia tetragonioides, Sclerolaena* spp.
Species richness: (0.1 ha) 24.7 ± 1.1 (n= 5)
Habitat (photopattern): More open than 8, some clumps of 4
Landform: Typically upslope of Black Bluebush on clay plain
Soil: Red sandy loam with nodules of calcrete in the top horizon
Degradation/regeneration: As for Black Bluebush. This shrubland also occurs with a mallee overstorey in restricted areas west of the Anabranch.

10. Lunette Shrubland

Map unit: 10
Code: kZ2F
Structural formation: Low shrubland
Height: 0.8–2 m
Cover: 10–30 %
Dominant species: *Maireana pyramidata, M. appressa*
Understorey species: *Sclerolaena* spp., *Atriplex* spp.
Species richness: No estimate
Habitat (photopattern): Gypseous dunes associated with lakes, including lunettes
Landform: Gypseous dunes associated with lakes, including lunettes
Soil: Saline gypseous clay mantling sand core
Degradation/regeneration: These landforms can erode to create spectacular features such as the Walls of China at Lake Mungo. Such erosion usually follows periods of over-grazing and trampling. Few perennial plants persist on lunettes and no regeneration was observed.

11. Bladder Saltbush

Map units: 11 (12, 15)
Code: kZ2F
Structural formation: Low shrubland
Height: 0.2–1 m
Cover: 10–30 %
Dominant species: *Atriplex vesicaria*
Understorey species: *Sclerostegia tenuis, Pachycornia triandra, Osteocarpum acropterum* var. *deminutum, Disphyma clavellatum*
Species Richness: (0.1 ha) 18.1 ± 2.1 (n= 5)
Landform: Lower Alluvium, alluvial plains
Habitat (photopattern): Fine-grained, often with pronounced curvilinear patterns from paleochannels
Soil: Grey-brown clay loam, surface cracked
Degradation/regeneration: Often heavily grazed, affecting the shrub vitality and cover. No seedling regeneration was observed in the study area throughout the survey period. Degraded areas may be invaded by *Nitraria billardieri.*

12. Pigface – Samphire

Map units: 12 (11, 15)
Code: kZ1F
Structural formation: Low open-shrubland.
Height: 0.1–0.4 m
Cover: <10%
Dominant species: *Disphyma clavellatum, Sclerostegia tenuis* (may have overstorey of *E. largiflorens*)
Understorey species: *Annual Atriplex, Sclerolaena* spp.
Species richness: No estimate
Landform: Saline flats
Habitat (photopattern): Associated with 15
Soil: Pale cream-grey cracking clay
Degradation/regeneration: It is generally considered that *Disphyma clavellatum* is now much reduced in abundance since settlement, due to grazing and trampling (Cunningham et al. 1981). This community may grade into saltpan.

13. Canegrass Swamp

Map units: 13 (11, 15)
Code: yG3F
Structural formation: Grassland
Height: 1–3 m
Cover: 30–70 %
Dominant species: *Eragrostis australasica, Muehlenbeckia cunninghamii*
Understorey species: Usually absent
Species richness: No estimate
Landform: Depressions in clay plain
Habitat (photopattern): With scattered trees of *Eucalyptus largiflorens*
Soil: Grey cracking clay
Degradation/regeneration: Subject to intermittent flooding where water remains several months. May have scattered trees of *Eucalyptus largiflorens.* Important wildlife habitat particularly for nesting waterbirds, although it can also harbour feral pigs.

14. Sedge Swamp

Map unit: 14
Code: gG3F.
Structural formation: Sedgeland
Height: 0–0.5 m
Cover: 30–70 %
Dominant species: *Eleocharis pallens*
Understorey species: Usually absent
Species richness: No estimate
Landform: Flats or depressions within Riverine Forest, margins of swamps, claypans and lakebeds
Habitat (photopattern): Flats within Riverine Forest
Soil: Variety of clay soil.
Degradation/regeneration: Responds quickly to rain and grows throughout the year if water is available. Only is grazed by stock if other more palatable species are unavailable.

15. Saltpan, Lakebed

Map units: 15, Lake
Code: kF2F
Structural formation: Open herbland
Height: 0–0.2 m
Cover: 10–30 %
Dominant species: *Sclerostegia tenuis, Muehlenbeckia cunninghamii, M. horrida* (edges)
Understorey species: *Atriplex leptocarpa, A. pseudocampanulata, Disphyma clavellatum*
Species richness: No estimate
Landform: Saltpan or clay flat often areas of groundwater discharge, some lakebeds
Habitat (photopattern): Saltpan or clay flat
Soil: Highly saline gypseous flats, fine-grained clay, large desiccation cracks
Degradation/regeneration: Many of the larger lakes are now cultivated and in such cases, all native vegetation has been destroyed..

Plant communities too small to be shown as separate map units

Sand Plain Mallee

Map units: 3, 5, 6, 7
Code: eS2H
Structural formation: Tall shrubland
Height: 6–10 m
Cover:10–30 %
Dominant species: *Eucalyptus oleosa, E. socialis, E. gracilis*
Understorey species: *Chenopodium curvispicatum, Ptilotus exaltatus* var. *exaltatus, Olearia muelleri*
Species richness: (0.1 ha) 23.7 ± 1.1 (n= 5)
Landform: Sand plain, sand ridges
Soil: Calcareous sandy red earth, red duplex soil
Degradation/regeneration: More easily cleared than Dune Mallee because of flatter topography and heavier soil. No eucalypt seedling regeneration noted.

Swale Mallee

Map units: 3, 5, 6, 7
Code: S2H
Structural formation: Tall shrubland
Height: 2–10 m
Cover: 10–30 %
Dominant species: *Eucalyptus gracilis, E. dumosa*
Understorey species: *Enchylaena tomentosa, Dissocarpus paradoxus, Senna artemisioides, Sclerolaena* spp.
Species richness: (0.1 ha) 34.2 ± 1.4 (= 5)
Landform: Swales between sand dunes and deflated sand plains
Soil: Calcareous red sand
Degradation/regeneration: More subject to clearing than the dune mallee. Often the sites for watering points and ground tanks and therefore prone to trampling and over-grazing.

Mixed Woodland, Callitris Woodland

Map units: 4, 11
Code: pM2S
Structural formation: Open woodland
Height: 8–12 m
Cover: 10–30 %
Dominant species: *Callitris glaucophylla, Hakea leucoptera, Hakea tephrosperma, Myoporum platycarpum*
Understorey species: *Maireana pyramidata*
Species richness: no estimate
Landform: Sandy rises adjacent to riverine flats, source-bordering dunes
Soil: Deep loose sandy soil. On sandhills along the Murray and lowermost part of the Darling, Murray Pine, *Callitris preissii* subsp. *murrayensis* occurs and also much *C. preissii–C. glaucophylla* hybridisation (L.A.S. Johnson pers. comm.)
Degradation/regeneration: often cleared for valuable timber trees and only identifiable by the landform and scattered remnant trees. Further east of the mapped area this landform is often cultivated for wheat and other cereal crops. Similar woodland may be found on sandy rises on the western sides of lakes as well, for example west of Popiltah Lake. Such stands are always of small area and cannot be mapped at the scales employed here.

Acacia Shrubland

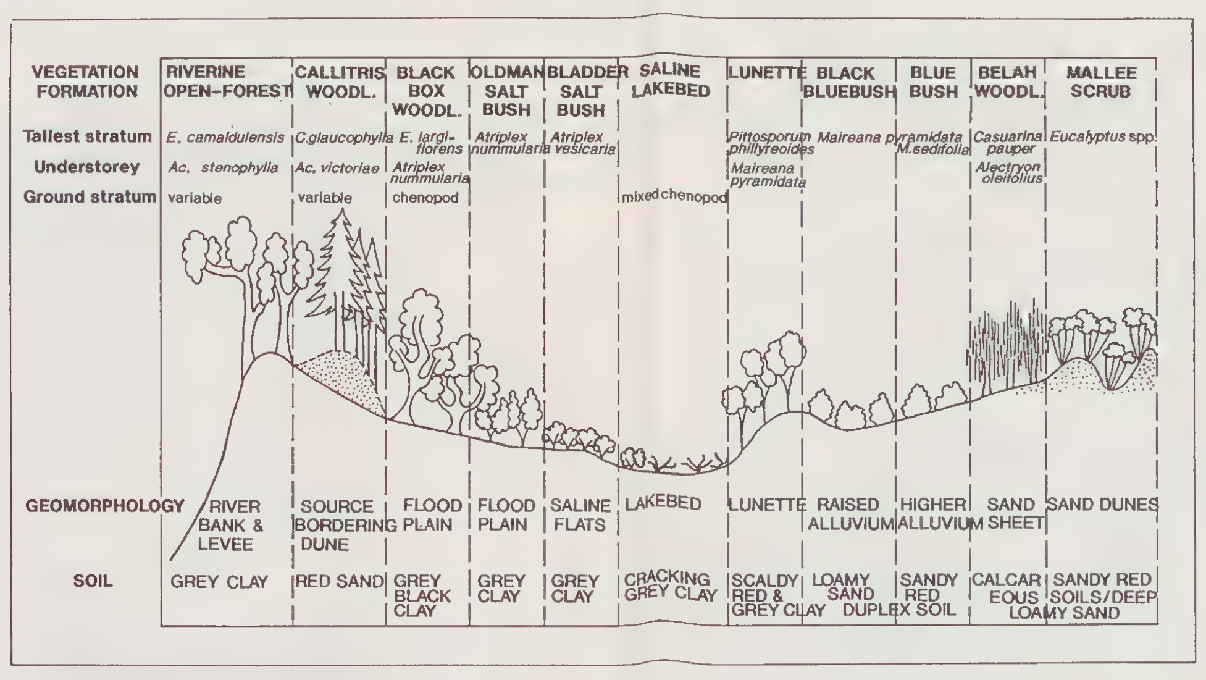
Map units: 1, 2, 4
Code: wS3F
Structural formation: Tall shrubland
Height: 2–6 m
Cover: 30–70%
Dominant species: *Acacia victoriae, Dodonaea, Acacia oswaldii*
Understorey species: *Sclerolaena* spp., *Maireana* spp.
Species richness: No estimate
Landform: Sandy rises such as source-bordering dunes which extend along rivers and major streams, creek beds and banks in a variety of landforms
Soil: Red sandy soil
Degradation/regeneration: Remnant trees of *Myoporum platycarpum, Hakea leucoptera, Hakea tephrosperma, Callitris glaucophylla* and *Callitris preissii* subsp. *murrayensis* may occur. This may represent highly disturbed areas that previously supported *Callitris* woodland. The dominant species may be mainly the 'woody weeds' which are invasive, colonising, native species.

Lignum Swamp

Map units: 2, 12, 14
Code: xS4F
Structural formation: Closed scrub
Height: 2–8 m
Cover: 70–100 %
Dominant species: *Muehlenbeckia cunninghamii* (*Eucalyptus camaldulensis, E. largiflorens* around edges)
Understorey species: Usually absent
Species richness: No estimate
Landform: Depressions with impounded water
Soil: Heavy clay
Degradation/regeneration: Very important wildlife habitat particularly for nesting waterbirds. Regenerates readily under favourable flood conditions.

Old Man Saltbush

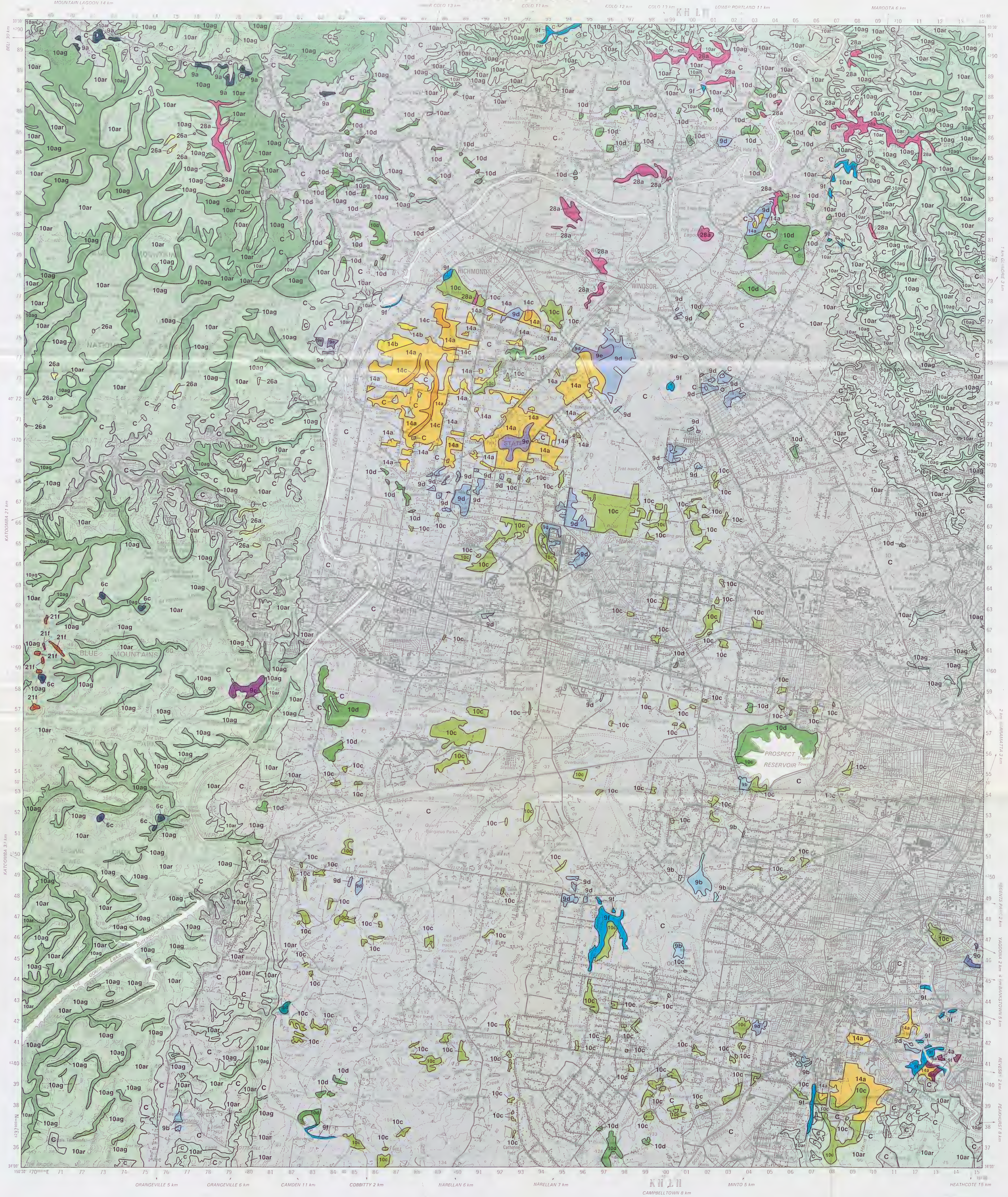
Map units: 2
Code: kS3F
Structural formation: Tall shrubland
Height: 1–2 m
Cover: 30–70 %
Dominant species: *Atriplex nummularia, Rhagodia spinescens,* (*Eucalyptus largiflorens*)
Understorey species: *Atriplex* spp., *Sclerolaena* spp.
Species richness: No estimate
Landform: River flat
Soil: Clay soils
Degradation/regeneration: Grades into *Maireana pyramidata* shrubland away from the river. These deeply rooted shrubs can withstand severe drought and also tolerate flooding, but can be decimated by heavy continuous grazing. Only small relict stands remain of what were more extensive stands (Cunningham et al. 1981).



Idealized vegetation continuum from river to sand dunes showing relative topographic arrangement of major vegetation types.

PENRITH

1:100 000 VEGETATION SERIES

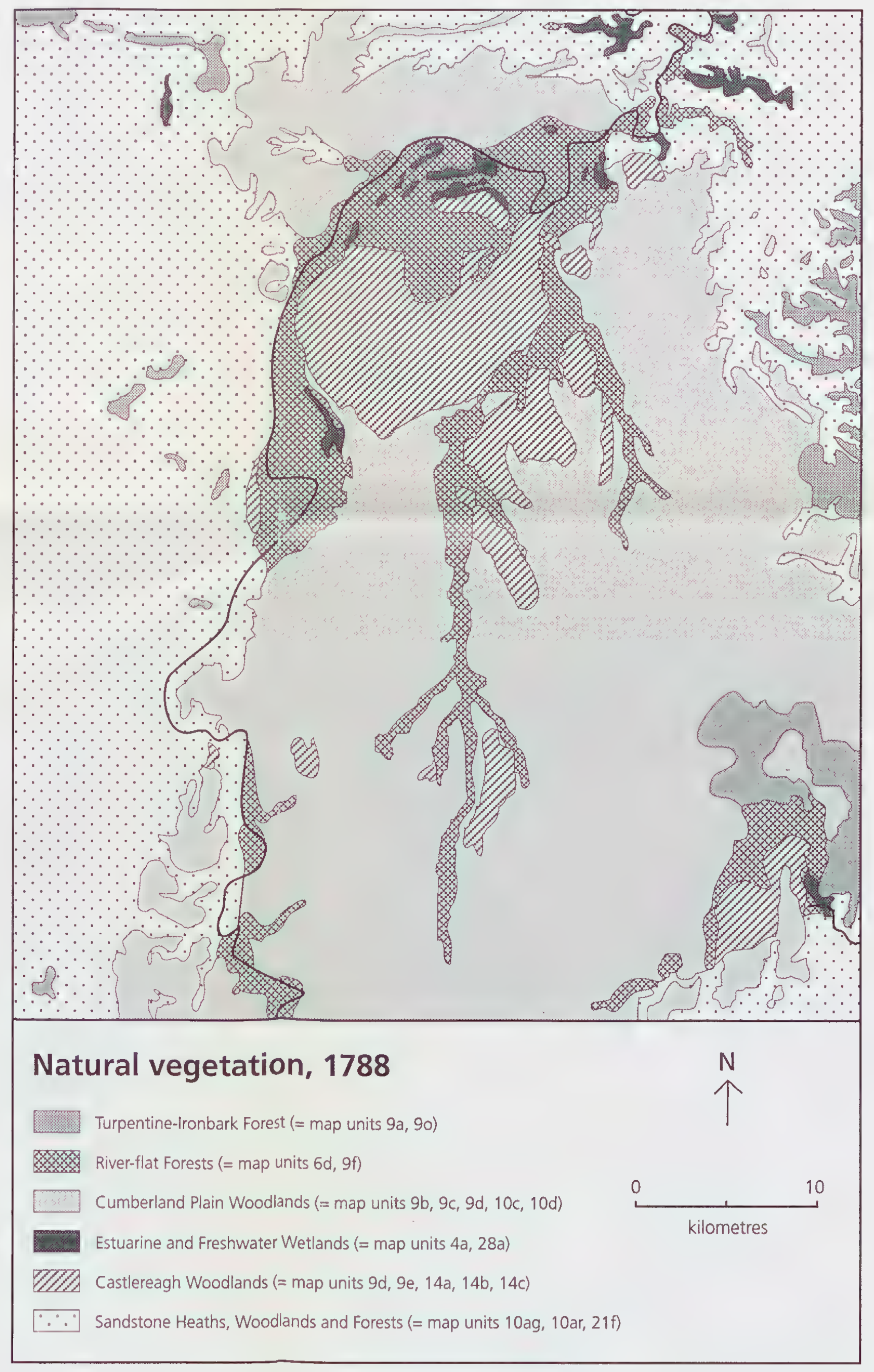


MAP UNIT DESCRIPTION

	MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	OCCURRENCE
■	4a	**Estuarine Complex**			
		Open-scrub	*Avicennia marina* *Aegiceras corniculatum*	Holocene alluvium	Estuarine mudflats regular tidal inundation
		Rushland/ Reedland	*Juncus kraussii* *Phragmites australis*		Infrequent inundation Brackish water
		Low open-forest	*Casuarina glauca*		
		Open-scrub	*Melaleuca ericifolia*		
■	6c	**Glen Forest**			
		Tall open-forest	*Eucalyptus deanei*	Diatremes	Isolated outcrops in Blue Mountains
■	6d	**Camden White Gum Forest**			
		Tall open-forest	*Eucalyptus benthamii*	Holocene alluvium	Confined to Nepean River at Bents Basin, Wallacia
■	9a	**Shale Cap Forest**			
		Open-forest	*Eucalyptus paniculata* *Eucalyptus notabilis*	Wianamatta Shale	Ridges along Bells road
■	9b	**Spotted Gum Forest**			
		Open-forest	*Eucalyptus maculata* *Eucalyptus moluccana*	Wianamatta Shale	On hills around Hoxton Park. Also around Werombi
■	9c	**Ironbark Forest**			
		Open-forest	*Eucalyptus crebra* *Eucalyptus fibrosa*	Wianamatta Shale	On shale remnants at Glenbrook
■	9d	**Shale/Gravel Transition Forest**			
		Open-forest	*Eucalyptus fibrosa* *Eucalyptus moluccana*	Wianamatta Shale/ Tertiary alluvium	On transition zone between these geological units
■	9e	**Castlereagh Ironbark Forest**			
		Open-forest	*Eucalyptus fibrosa*	Tertiary alluvium	Castlereagh area on clay soils
■	9f	**River-flat Forest**			
		Open-forest	*Angophora subvelutina* *Eucalyptus amplifolia* *Eucalyptus tereticornis*	Holocene alluvium	Alluvial flood plains along Nepean - Hawkesbury River and major tributary creeks
■	9o	**Turpentine-Ironbark Forest**			
		Open-forest	*Syncarpia glomulifera* *Eucalyptus paniculata*	Wianamatta Shale	Bankstown area
■	10ag	**Sydney Sandstone Complex Sydney Sandstone Gully Forest**			
		i) Tall open-forest	*Eucalyptus deanei* *or Eucalyptus saligna* *Angophora floribunda* *Syncarpia glomulifera*	Hawkesbury Sandstone/ Narrabeen Group	Sheltered gullies Hillsides Sheltered gorges
		ii) Closed-forest	*Ceratopetalum apetalum* *Doryphora sassafras*		
		iii) Open-forest	*Eucalyptus piperita* *Angophora costata* *+/- Eucalyptus pilularis*	Hawkesbury Sandstone	Gullies, sheltered hillsides

MAP UNIT DESCRIPTION

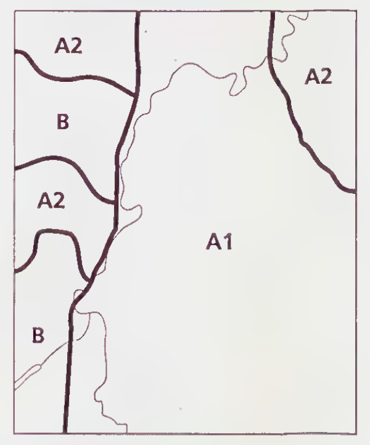
	MAP UNIT	STRUCTURE	MAIN CANOPY SPECIES	GEOLOGY	OCCURRENCE
■	10ar	**Sydney Sandstone Ridgetop Woodland**			
		i) Low open-forest	*Eucalyptus sieberi* *Eucalyptus piperita*	Hawkesbury Sandstone	Ridgetops and plateaus >1200mm pa rainfall
		ii) Woodland/ Open woodland	*Eucalyptus gummifera* *Eucalyptus eximia* *Eucalyptus sparsifolia* *Angophora costata* *Angophora bakeri*	Hawkesbury Sandstone	Ridges and dry exposed hillsides
		iii) Open-forest/ woodland	*Eucalyptus gummifera* *Angophora costata* *Eucalyptus notabilis* *Eucalyptus sparsifolia* *Eucalyptus punctata* *Syncarpia glomulifera*	Hawkesbury Sandstone with clay influence	Ridges
		iv) Open-scrub	*Angophora hispida*		Broad plateau surfaces
■	10c	**Grey Box Woodland**			
		Woodland	*Eucalyptus moluccana* *Eucalyptus tereticornis*	Wianamatta Shale	Flat to gently undulating basin of Cumberland Plain. Clay soils
■	10d	**Grey Box-Ironbark Woodland**			
		Woodland	*Eucalyptus moluccana* *Eucalyptus tereticornis* *Eucalyptus crebra*	Wianamatta Shale	Undulating to hilly country on margins of Cumberland Plain. Clay soils
■	14a	**Castlereagh Scribbly Gum Woodland**			
		Low woodland	*Eucalyptus sclerophylla* *Angophora bakeri*	Tertiary alluvium	Castlereagh-Londonderry and Holsworthy on sandy soils
■	14b	**Agnes Banks Woodland**			
		Low woodland/ open-scrub	*Eucalyptus sclerophylla* *Angophora bakeri* *Banksia serrata*	Tertiary alluvium	Confined to sand deposit at Agnes Banks
■	14c	**Swamp Woodland**			
		Low woodland	*Eucalyptus parramattensis*	Tertiary alluvium	Poorly drained depressions and creek lines
■	21f	**Lower Blue Mountains Heath**			
		Open-heath	*Eucalyptus stricta* *Allocasuarina nana*	Hawkesbury Sandstone	Dry, rocky ridge tops
■	26a	**Blue Mountains Sedge Swamps**			
		Closed-sedgeland	*Gymnoschoenus sphaerocephalus* *Lepidosperma limicola* *Xyris ustulata* *Baeckea linifolia*	Hawkesbury Sandstone	Poorly-drained sites on plateau
■	28a	**Freshwater Reed Swamps**			
		Open-sedgeland	*Eleocharis sphacelata* *Juncus usitatus* *Persicaria spp.*	Holocene alluvium	Freshwater swamps
■	C	**Cleared**	These areas are generally the better agricultural soils along the river alluvial flats or on the Wianamatta Shale country. Small remnants of native vegetation too small to show on the map may occur here.		



Natural vegetation, 1788

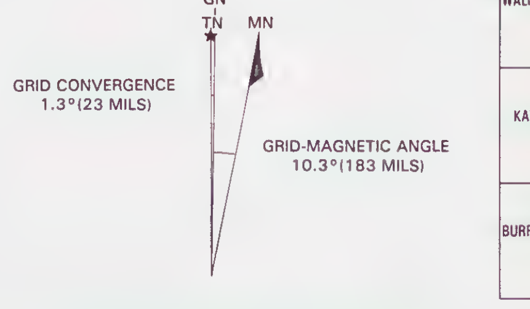
- ▒ Turpentine-Ironbark Forest (= map units 9a, 9o)
- ▩ River-flat Forests (= map units 6d, 9f)
- ░ Cumberland Plain Woodlands (= map units 9b, 9c, 9d, 10c, 10d)
- ■ Estuarine and Freshwater Wetlands (= map units 4a, 28a)
- ▨ Castlereagh Woodlands (= map units 9d, 9e, 14a, 14b, 14c)
- ⁚ Sandstone Heaths, Woodlands and Forests (= map units 10ag, 10ar, 21f)

Map Reliability



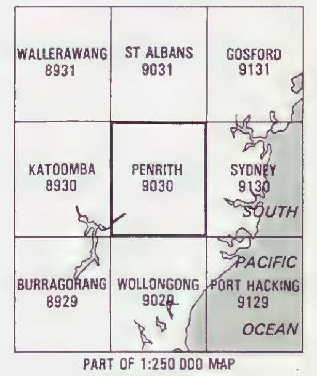
A1 Aerial photograph interpretation with extensive field reconnaissance.
A2 Aerial photograph interpretation with limited field reconnaissance.
B Aerial photograph interpretation only.

Aerial photography 1979, 1989.


GN
TN
MN
GRID CONVERGENCE 1.3°(23 MILS)
GRID-MAGNETIC ANGLE 10.3°(183 MILS)

TRUE NORTH, GRID NORTH AND MAGNETIC NORTH ARE SHOWN DIAGRAMMATICALLY FOR THE CENTRE OF THIS MAP. MAGNETIC NORTH IS CORRECT FOR 1975 AND MOVES EASTERLY BY 0.1°(2 MILS) IN ABOUT THREE YEARS.

INDEX TO ADJOINING MAPS



PART OF 1:250 000 MAP
SI 56-5 SYDNEY

Topographic base from Penrith 9030, 1:100,000 Map Sheet, Australian Surveying & Land Information Group, Department of Administrative Services. Thematic information drawn and colour separated by Cartoscope Pty Ltd and printed by Dynamic Press.

ELEVATION IN METRES. CONTOUR INTERVAL 20 METRES.

SCALE 1:100,000

Kilometres 2 0 2 4 6 8 10 Kilometres

NATURAL VEGETATION of the PENRITH area

D.H. Benson

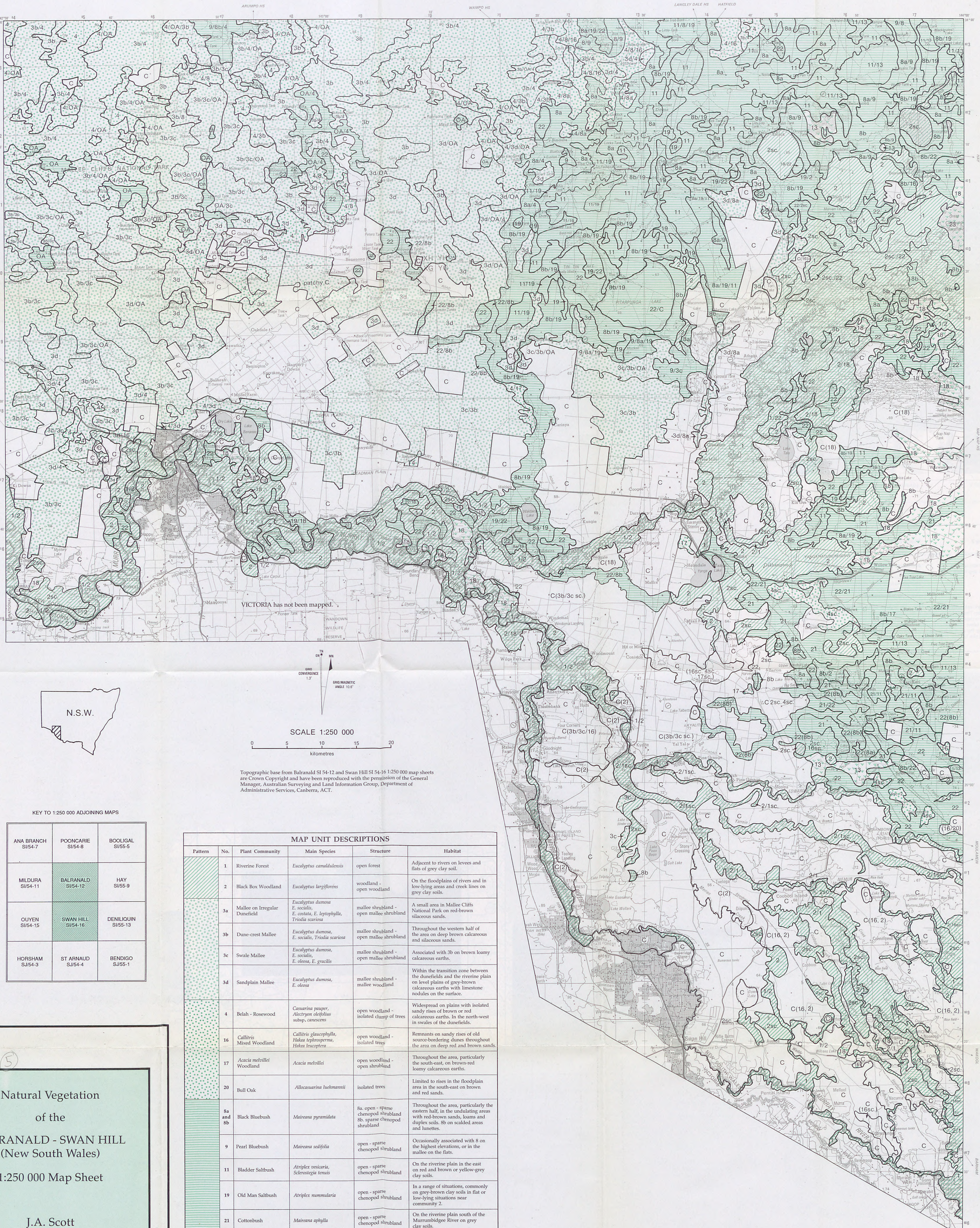
Detailed descriptions of the plant communities are given in CUNNINGHAMIA Volume 2, Number 4, 1992

Compiled and prepared at the
NATIONAL HERBARIUM OF NEW SOUTH WALES,
ROYAL BOTANIC GARDENS, SYDNEY.

Understanding the ecology of our native plants.

BALRANALD - SWAN HILL

1:250 000 VEGETATION SERIES



VICTORIA has not been mapped.

Topographic base from Balranald SI 54-12 and Swan Hill SI 54-16 1:250 000 map sheets are Crown Copyright and have been reproduced with the permission of the General Manager, Australian Surveying and Land Information Group, Department of Administrative Services, Canberra, ACT.

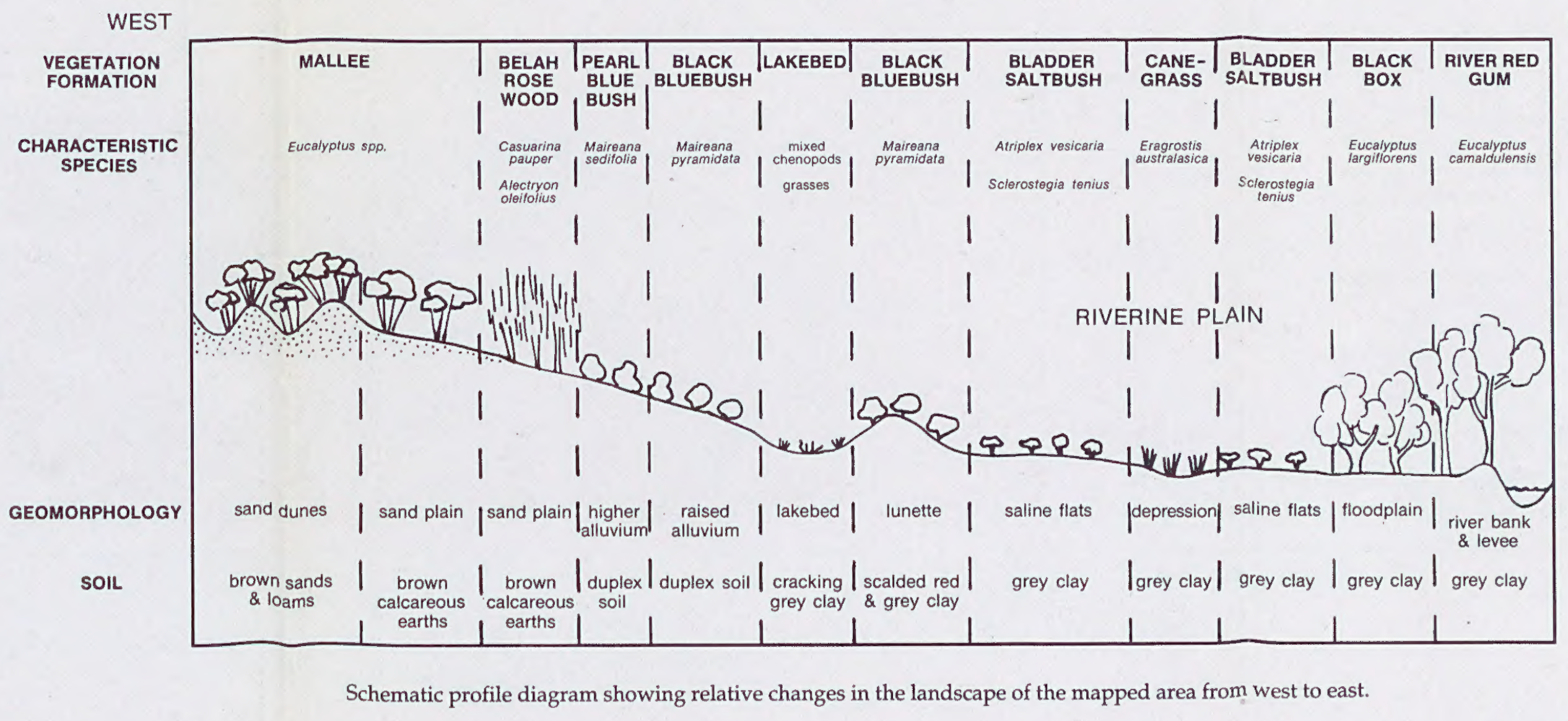
KEY TO 1:250 000 ADJOINING MAPS

ANA BRANCH SI/54-7	POONCARIE SI/54-8	BOOLIGAL SI/55-5
MILDURA SI/54-11	BALRANALD SI/54-12	HAY SI/55-9
OUYEN SI/54-15	SWAN HILL SI/54-16	DENILIQUIN SI/55-13
HORSHAM SJ/54-3	ST ARNAUD SJ/54-4	BENDIGO SJ/55-1

MAP UNIT DESCRIPTIONS

Pattern	No.	Plant Community	Main Species	Structure	Habitat
▨	1	Riverine Forest	*Eucalyptus camaldulensis*	open forest	Adjacent to rivers on levees and flats of grey clay soil.
	2	Black Box Woodland	*Eucalyptus largiflorens*	woodland - open woodland	On the floodplains of rivers and in low-lying areas and creek lines on grey clay soils.
○	3a	Mallee on Irregular Dunefield	*Eucalyptus dumosa* *E. socialis,* *E. costata, E. leptophylla,* *Triodia scariosa*	mallee shrubland - open mallee shrubland	A small area in Mallee Cliffs National Park on red-brown silaceous sands.
	3b	Dune-crest Mallee	*Eucalyptus dumosa,* *E. socialis, Triodia scariosa*	mallee shrubland - open mallee shrubland	Throughout the western half of the area on deep brown calcareous and silaceous sands.
	3c	Swale Mallee	*Eucalyptus dumosa,* *E. socialis,* *E. oleosa, E. gracilis*	mallee shrubland - open mallee shrubland	Associated with 3b on brown loamy calcareous earths.
	3d	Sandplain Mallee	*Eucalyptus dumosa,* *E. oleosa*	mallee shrubland - mallee woodland	Within the transition zone between the dunefields and the riverine plain on level plains of grey-brown calcareous earths with limestone nodules on the surface.
●	4	Belah - Rosewood	*Casuarina pauper,* *Alectryon oleifolius* subsp. *canescens*	open woodland - isolated clump of trees	Widespread on plains with isolated sandy rises of brown or red calcareous earths. In the north-west in swales of the dunefields.
	16	*Callitris* Mixed Woodland	*Callitris glaucophylla,* *Hakea tephrosperma,* *Hakea leucoptera*	open woodland - isolated trees	Remnants on sandy rises of old source-bordering dunes throughout the area on deep red and brown sands.
	17	*Acacia melvillei* Woodland	*Acacia melvillei*	open woodland - open shrubland	Throughout the area, particularly the south-east, on brown-red loamy calcareous earths.
	20	Bull Oak	*Allocasuarina luehmannii*	isolated trees	Limited to rises in the floodplain area in the south-east on brown and red sands.
▤	8a and 8b	Black Bluebush	*Maireana pyramidata*	8a. open - sparse chenopod shrubland 8b. sparse chenopod shrubland	Throughout the area, particularly the eastern half, in the undulating areas with red-brown sands, loams and duplex soils. 8b on scalded areas and lunettes.
	9	Pearl Bluebush	*Maireana sedifolia*	open - sparse chenopod shrubland	Occasionally associated with 8 on the highest elevations, or in the mallee on the flats.
	11	Bladder Saltbush	*Atriplex vesicaria,* *Sclerostegia tenuis*	open - sparse chenopod shrubland	On the riverine plain in the east on red and brown or yellow-grey clay soils.
	19	Old Man Saltbush	*Atriplex nummularia*	open - sparse chenopod shrubland	In a range of situations, commonly on grey-brown clay soils in flat or low-lying situations near community 2.
	21	Cottonbush	*Maireana aphylla*	open - sparse chenopod shrubland	On the riverine plain south of the Murrumbidgee River on grey clay soils.
	22	Dillon bush	*Nitraria billardieri*	sparse shrubland	In disturbed areas on plains, floodplains and dry lakebeds on clay and loam soils often saline.
	OA	Open Areas	various shrubs and grasses	sparse chenopod shrubland - grassland	Areas of heavier soil within the mallee often along natural drainage lines, or disturbed areas.
ѵ	13	Canegrass	*Eragrostis australasica*	grassland	In low-lying depressions on the riverine plain on grey clay soils.
	18	Lignum	*Muehlenbeckia florulenta*	shrubland - open shrubland	On river floodplains where grey clay soils are infrequently flooded.
	23	Great Cumbung Swamp	*Phragmites australis* *Senecio cunninghamii*	closed - open herbland	On the eastern edge of the area within the floodplain on heavy clay soils.
	C	Cleared and/or cropped	Native vegetation has largely been removed for agricultural or urban development but remnant vegetation of varying sizes and condition may remain. Where possible pre-cleared vegetation and remnants have been indicated in brackets following C.		
	sc.	scattered	Trees are scattered.		

Present day vegetation as of Jan 1991. Clearing marked from LANDSAT Jan 1991.



	MALLEE		BELAH ROSE WOOD	PEARL BLUE BUSH	BLACK BLUEBUSH	LAKEBED	BLACK BLUEBUSH	BLADDER SALTBUSH	CANE-GRASS	BLADDER SALTBUSH	BLACK BOX	RIVER RED GUM
CHARACTERISTIC SPECIES	*Eucalyptus spp.*		*Casuarina pauper* *Alectryon oleifolius*	*Maireana sedifolia*	*Maireana pyramidata*	mixed chenopods grasses	*Maireana pyramidata*	*Atriplex vesicaria* *Sclerostegia tenius*	*Eragrostis australasica*	*Atriplex vesicaria* *Sclerostegia tenius*	*Eucalyptus largiflorens*	*Eucalyptus camaldulensis*
GEOMORPHOLOGY	sand dunes	sand plain	sand plain	higher alluvium	raised alluvium	lakebed	lunette	saline flats	depression	saline flats	floodplain	river bank & levee
SOIL	brown sands & loams	brown calcareous earths	brown calcareous earths	duplex soil	duplex soil	cracking grey clay	scalded red & grey clay	grey clay	grey clay	grey clay	grey clay	grey clay

Schematic profile diagram showing relative changes in the landscape of the mapped area from west to east.

1456c (5)

Natural Vegetation

of the

BALRANALD - SWAN HILL
(New South Wales)

1:250 000 Map Sheet

J.A. Scott

Descriptions of the plant communities are given in Cunninghamia 2(4) 1992

Compiled and prepared at the
National Herbarium of New South Wales

ROYAL BOTANIC GARDENS SYDNEY

Understanding the ecology of our native plants

PLANT COMMUNITIES OF THE

BALRANALD - SWAN HILL 1:250 000 MAP SHEET

Community 1

Riverine Forest

Structure: open forest * & **

Characteristic species	Associated species
Eucalyptus camaldulensis (River Red Gum)	*Muehlenbeckia florulenta,* *Wahlenbergia fuminalis, Paspalidium jubiflorum* *Acacia stenophylla, Eucalyptus largiflorens* *Cynodon dactylon, Ranunculus lappaceus* *Brachycome basaltica* var. *gracilis*

On the extensive floodplain of the Murrumbidgee River two subunits have been described by Pressey *et al.* (1984).

Levees	Floodplain
Eucalyptus camaldulensis *Carex appressa* **Cirsium vulgare* *Wahlenbergia fluminalis* *Pratia concolor* *Paspalidium jubiflorum* **Sonchus oleraceus*	*Eucalyptus camaldulensis* *Marsilea drummondii, Phragmites australis* *Eragrostis australasica, Centipeda minima* *Pratia concolor, Ranunculus lappaceus* *Chenopodium nitrariacium* *Atriplex nummularia*

Soils: levees of grey, massive, non-cracking clays; at low elevations strongly gilgaid, grey self-mulching clays to massive non-cracking clays near the top of the floodplain (Pressey *et al.* 1984).
Occurrence: This community is found on the banks nearest the channels of the major rivers and creeks throughout the region, and on low-lying flats subject to flooding. The largest area of this community is found in the Lowbidgee District along the Murrumbidgee River. The densest stands of this community are along the banks nearest the river channels. Extensive areas on the flats have a more "open woodland" structure. For the length of the Murrumbidgee River within the mapped area, Black Box *Eucalyptus largiflorens* usually occurs as an adjacent community (2) on the floodplain flats. On parts of the Murray River the floodplain is much narrower and often the River Red Gum forest is abruptly bounded by higher ground of red/brown earths supporting mallee or *Callitris* mixed woodland, much of which has been cleared. This is most apparent along the stretch of the Murray River between the points of entry of the Wakool and Murrumbidgee Rivers.

Community 2

Black Box

Structure: woodland *, woodland - open woodland **

Characteristic species	Associated species
Eucalyptus largiflorens	*Chenopodium nitrariacium* *Atriplex nummularia, Muehlenbeckia florulenta* *Enchylaena tomentosa, Sclerolaena tricuspis* *Einadia nutans,* often with *Atriplex lindleyi,* *Chamaesyce drummondii*

Soils: Grey clays rarely cracking and with a flat or gently undulating surface.
Occurrence: Throughout the region on the uppermost level of the floodplain; beyond the floodplain it may occur in depressions along creeks, drains and old stream beds (eg. Box Creek), and fringing ephemeral lakes. Examples of this community include Yanga Nature Reserve, the floodplain just west of Euston on the south side of the Sturt Highway, and ringing many of the lakes such as Lake Marimley, Lake Talbetts, Harveys Lake and Chillichil Lake.

Community 3

Mallee

3a Mallee on Irregular Dunefield

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species	Associated species
Eucalyptus dumosa, E. socialis, *E. costata, E. leptophylla* *E. oleosa, Triodia scariosa*	*Olearia muelleri, Grevillea huegelii,* *Acacia colletioides,* *Bossiaea walkeri*

Soils: Deep red-brown siliceous sands (Eldridge 1985).
Occurrence: The only area is in Mallee Cliffs National Park just north of Chalky Tank; it occurs more commonly to the north on the Pooncarie map.

3b Dune-crest Mallee

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species	Associated species
Eucalyptus socialis, *Eucalyptus dumosa,* *Eucalyptus gracilis,* *Triodia scariosa*	*Olearia pimelioides, Acacia colletioides* *Dodonaea viscosa* subsp. *angustissima* *Eremophila glabra, Eucalyptus costata,* *Senna artemisioides* subsp. *filifolia,* *Chenopodium curvispicatum* *Maireana pentatropis, Westringia rigida,* *Myoporum platycarpum,* occasional *Callitris verrucosa.*

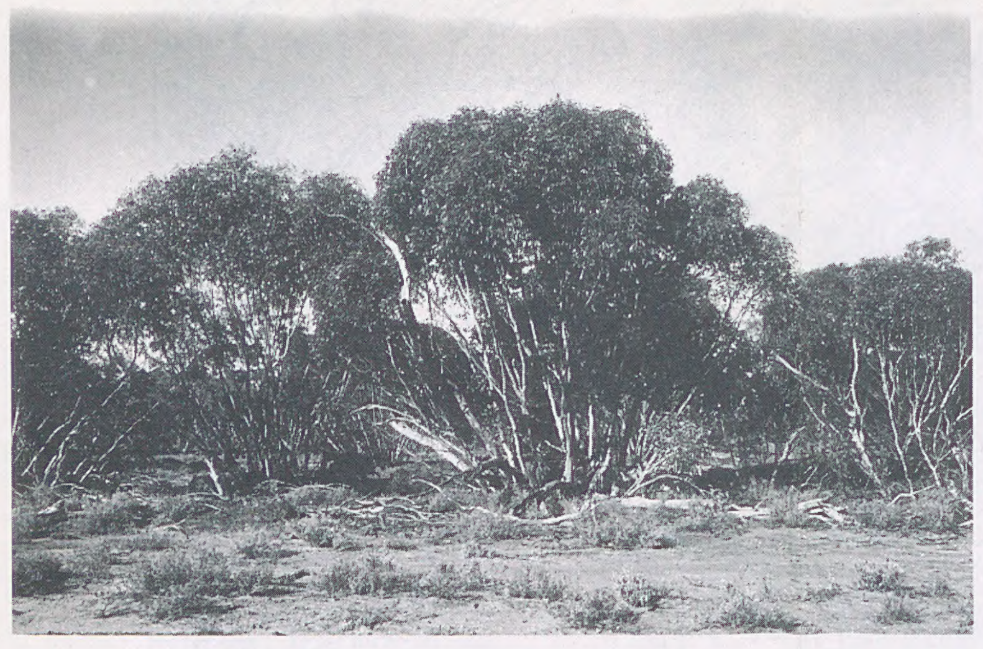
Soils: Deep brown calcareous and siliceous sands (Eldridge 1985).
Occurrence: Throughout the western half of the map sheet on the aeolian sands. In the north-west it is associated with Belah - Rosewood woodland (community 4) which occurs in the swales. This pattern is more common on the Ana Branch map sheet in the north-west, mapped as unit 5 by Fox (1991).

3c Swale Mallee

Structure: tall shrubland *; mallee shrubland - open mallee shrubland **

Characteristic species	Associated species
Eucalyptus dumosa, *Eucalyptus socialis,* *Eucalyptus oleosa,* *Eucalyptus gracilis*	*Enchylaena tomentosa, Maireana pentatropis,* *Maireana sclerolaenoides,* *Atriplex stipitata, Zygophyllum apiculatum,* *Zygophyllum aurantiacum, Westringia rigida,* *Senna artemisioides* subsp. *filifolia,* *Sclerolaena obliquicuspis,* *Acacia colletioides,* *Dodonaea viscosa* subsp. *angustissima.*

Soils: Brown loamy calcareous earths (Eldridge 1985).
Occurrence: Throughout the dune fields on the western half of the map sheet associated with the Dune-Crest Mallee community 3b, particularly south of the mosaic pattern of 3b/4. Isolated Belah *(Casuarina pauper)* occurs in some of the swales.



3d Sandplain Mallee

Structure: tall shrubland *; mallee shrubland - mallee woodland **

Characteristic species	Associated species
Eucalyptus dumosa *Eucalyptus oleosa*	*Atriplex stipitata, Zygophyllum apiculatum,* *Zygophyllum aurantiacum,* *Maireana pyramidata, Maireana pentatropis,* *Maireana* spp., *Enchylaena tomentosa,* *Sclerolaena obliquicuspis,* *Chenopodium curvispicatum,* **Psilocaulon tenue, Dissocarpus paradoxus,* some *Eucalyptus gracilis*

Soils: Grey-brown loam to clay-loam calcareous earths on extensive level plains often with limestone nodules on the surface (Eldridge 1985).
Occurrence: Within the transition zone between aeolian and alluvial landscapes, on southern part of the Willandra Lakes system. Flat plains with no dunes.

Community 4

Belah - Rosewood

Structure: woodland *; open woodland - isolated clumps **

Characteristic species	Associated species
Casuarina pauper *Alectryon oleifolius* subsp. *canescens*	*Exocarpos aphyllus, Olearia muelleri,* *Myoporum platycarpum,* *Enchylaena tomentosa, Einadia nutans,* *Sclerolaena* spp., *Maireana* spp. *Geijera parviflora* in the larger stands in the north.

Soils: Brown calcareous earths on plains with isolated sandy rises; deep brown and red loam to loamy sands.
Occurrence: This woodland is widespread throughout the mapped area. In the far north of the map in the mallee sand - dune country it occurs in the low lying areas of the swales where the soil is heavier. These areas were too small to map separately but due to their consistent recurring pattern are shown as a mosaic unit (mapped as 3b/4). This unit is more extensive to the north-west of the map on the Ana Branch - Mildura sheet (Fox 1991).
Larger areas of this community have been delineated, such as the band to the north-west of 'Bidura'. Much of this has been cleared for crops. This was also the case further south in the Sandplain Mallee, unit 3d, just north of the Sturt Highway. It is also associated with old lake and river systems in the north-east of the map, often seen with *Callitris* Mixed Woodland in undulating country.
Dotted in the south-east on heavy clay soils associated with the floodplains between the Murrumbidgee and Edward Rivers in close proximity to unit 2, *Eucalyptus largiflorens*, Belah (*Casuarina pauper*) dominates the groves, many of which are cleared or thinned. With further sampling this may be seen as a separate unit from that in the north.

Community 8

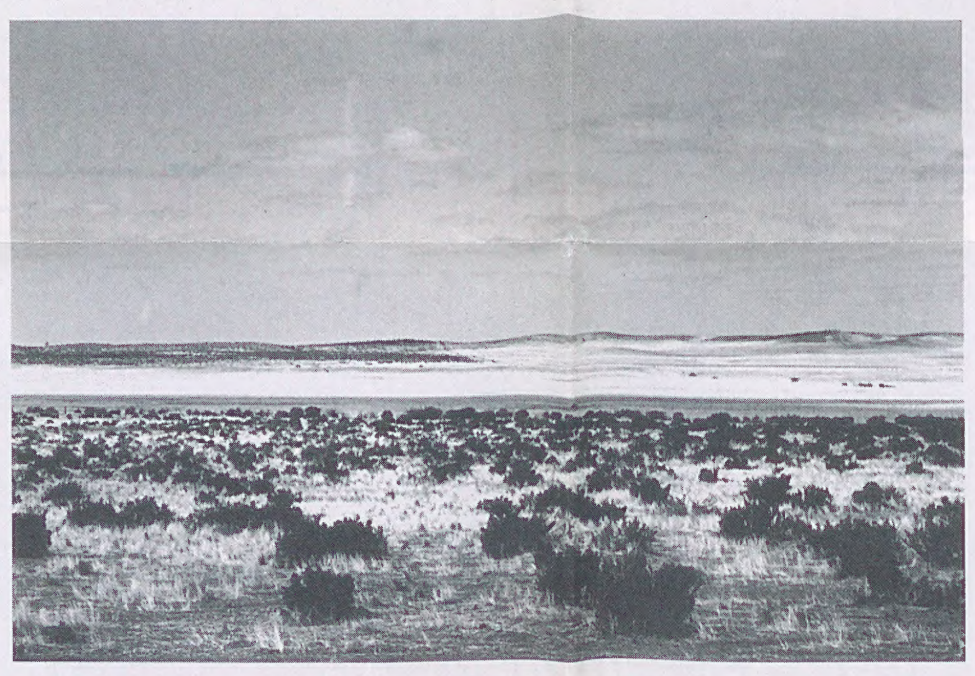
Black Bluebush

Structure: low shrubland - low open shrubland *; open chenopod shrubland - sparse chenopod shrubland **

8a.Characteristic species	Associated species
Maireana pyramidata	*Rhagodia spinescens, Enchylaena tomentosa,* *Atriplex* spp., *Sclerolaena* spp., *Stipa nodosa, Stipa elegantissima,* annuals.

8b. = same community as above but a more sparse shrubland usually on scalded areas often associated with areas along old stream beds and lunettes, or areas that have been particularly overgrazed and/or cleared.

Soils: Red-brown sand and loam duplex soils. Deep sandy soils in which limestone exists at a greater depth than 1.2 m below the surface (Beadle 1948).
Occurrence: This community occurs throughout the whole map area, most common in the transition zone between the aeolian sand dune country and the riverine plain. It is closely associated with lunettes and source bordering dunes of old river systems. The best stands are in the north-east corner of the map through to the boundary with the mallee country to the west. However, it also occurs south-east of Balranald. It may occur as the understorey of an adjacent woodland, such as Belah - Rosewood *Casaurina pauper - Alectryon oleifolius* subsp. *canescens* (community 4) near 'Prungle', or of mallee such as on the Prungle Mail road.



Community 9

Pearl Bluebush

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species	Associated species
Maireana sedifolia	*Enchylaena tomentosa, Rhagodia spinescens,* *Stipa elegantissima, Maireana pyramidata.*

Soils: Red-brown sand or loam duplex soils. Deep sandy soils in which limestone exists less than 60 cm below the surface (Beadle 1948).
Occurrence: Closely associated with Black Bluebush (*Maireana pyramidata*) (community 8) usually on slightly higher ground, such as on the crest of rises in the undulating country in the north-east sector of the map. Occasionally occurs in open areas within the mallee country such as to the north of and along the eastern boundary of Mallee Cliffs National Park.

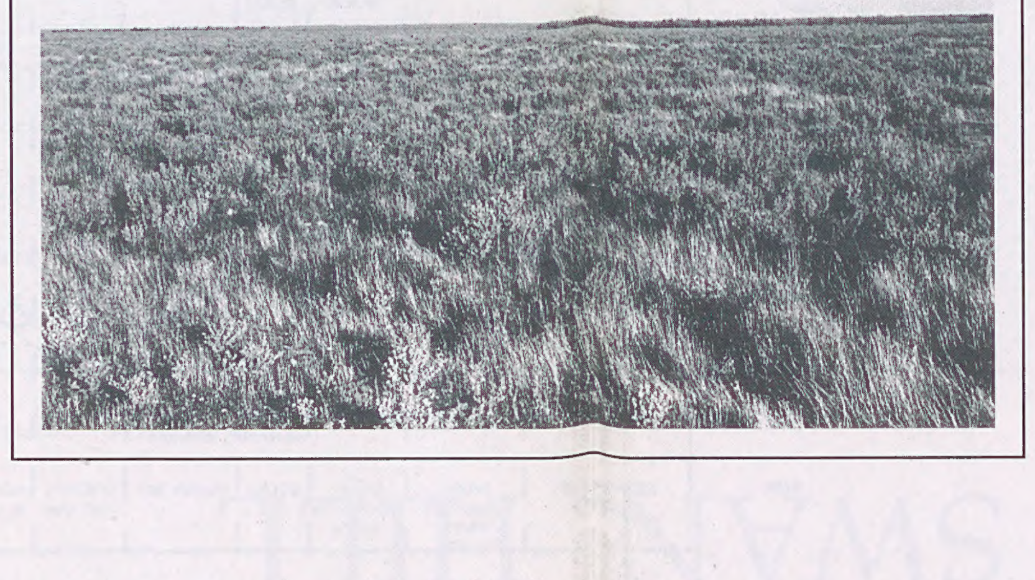
Community 11

Bladder Saltbush with *Sclerostegia tenuis*

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species	Associated species
Atriplex vesicaria, *Sclerostegia tenuis*	*Malacocera tricornis, Disphyma clavellatum,* *Dissocarpus biflorus* var. *biflorus,* *Brachycome trachycarpa,* annuals such as *Plantago drummondii, Senecio glossanthus,* *Brachycome leariloba, Rhodanthe corymbiflora,* **Lamarckia aurea, *Bromus rubens*

Soils: Red and brown or yellow-grey compact clay or clay-loam soils.
Occurrence: In the eastern half of the region, the vastest areas in the north. It is often broken by areas of *Maireana pyramidata* (community 8) and *Atriplex nummularia* (community 19).



Community 13

Canegrass

Structure: grassland * & **

Characteristic species	Associated species
Eragrostis australasica	*Eleocharis pallens, Juncus aridicola,* *Juncus flavidus, Muehlenbeckia florulenta*

Soils: Slightly saline, compact heavy grey clay soils on which water is ponded for several months (Cunningham 1981).
Occurrence: Generally throughout the eastern-half of the area in low-lying areas of swamps, table-drains and claypans within the chenopod shrubland communities 11 and 21. Typically occurring in small depressions (each one unmappable at this scale) within *Atriplex vesicaria - Sclerostegia tenuis* shrublands (community 11) in the north-east of the map. Areas with the highest occurrence of Canegrass depressions have been mapped as a mosaic unit 11/13. Also occurs along the old creek line of Box Creek on the Prungle Mail road. It is seen in larger stands south-west of Perekerten and may grow with Lignum and in the riverine communities.

Community 16

Callitris Mixed Woodland

Structure: open woodland *; open woodland - isolated trees **

Characteristic species	Associated species
Callitris glaucophylla, *Hakea leucoptera,* *Hakea tephrosperma*	*Eremophila longifolia,* *Dodonaea viscosa* subsp. *angustissima,* *Pittosporum phillyreoides,* also at times with *Alectryon oleifolius* subsp. *canescens,* *Casuarina pauper* or *Allocasuarina luehmannii,* *Acacia melvillei, Geijera parviflora.*

Near the Murray River *Callitris preissii* subsp. *murrayensis* may replace *Callitris glaucophylla.*

Soils: Deep coarse textured red and brown sands and sand-loams.
Occurrence: Usually as remnants on elevated red sandy ridges occurring throughout the region, usually corresponding to old source bordering dunes of prior streams and lakes. More common in the south-east such as near Condoulpe Lake south of Balranald, though much of this has been cleared. One of the best remnants is 2 km north-east of 'Lyle' but this would have been more extensive in the past. Raised areas of old lunette remnants on the Murrumbidgee floodplain have remnants of this community often with *Maireana pyramidata.* These areas have been heavily grazed and much of the previous shrubs have been removed (Pressey *et al.* 1984).
Callitris glaucophylla with or without associated species may occur in association with Belah - Rosewood (community 4) in the mallee dune country and the undulating country in the north to the Balranald - Ivanhoe road.

Community 17

Acacia melvillei Woodland

Structure: tall shrubland - low woodland *; open woodland - open shrubland **

Characteristic species	Associated species
Acacia melvillei	*Enchylaena tomentosa, Sida corrugata,* *Rhagodia spinescens, Nitraria billardieri* *Medicago* spp., *Tetragonia tetragonioides,* *Goodenia fascicularis & Zygophyllum* spp.

Soils: Brown-red loamy calcareous earths.
Occurrence: *Acacia melvillei* may form groves as a single dominant species. The largest of these is located just to the south and the north of the town of Balranald, where they are large enough to be mapped as a separate unit. Grazing of stock and rabbits resulted in a sparse understorey. Some resprouting of the acacias occurs, but generally very little regeneration is to be seen at present.
Groves of smaller size occur throughout the area, less so in the mallee of the north-west. *Acacia melvillei* also appears dotted throughout the south-east of the map area, often as one or two trees, possibly remnants of once larger areas that have been cleared or grazed.

Community 18

Lignum

Structure: open scrub *; shrubland - open shrubland **
This unit was not sampled, so information has been taken from literature.

Murray River floodplain	Murrumbidgee (Pressey *et al.* 1984)
(Margules & Partners *et al.* 1990) *Muehlenbeckia florulenta,* *Einadia nutans, *Bromus rubens,* with or without *Chenopodium nitrariaceum*	*Muehlenbeckia florulenta, *Medicago* spp., *Senecio cunninghamii, *Phalaris paradoxa*

Soils: Strongly gilgaied, grey self-mulching clay soils (Pressey *et al.* 1984)
Occurrence: This community generally occurs on the floodplains at a higher elevation than *Eucalyptus camaldulensis* around the fringes of grey soil open country (Pressey *et al.* 1984). It is most abundant in Lowbidgee Area, under River Red Gum (*Eucalyptus camaldulensis*) and Black Box (*Eucalyptus largiflorens*) or as vast areas of monospecific stands. On the road to 'Yanga' much of the Lignum has been cleared for cropping.

Community 19

Old Man Saltbush

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species	Associated species
Atriplex nummularia	*Atriplex vesicaria, Rhagodia spinescens* *Atriplex* spp., *Sclerolaena* spp.

Soils: Mostly on grey and brown clay soils, usually in flat or low-lying situations. Can be found on practically all soils and at all levels (Cunningham *et al.* 1981).
Occurrence: Throughout the mapped area except the mallee, in a range of situations. Most often on grey clay soils near *Eucalyptus largiflorens* woodlands and along drainage lines. The largest areas are just north of Yanga Nature Reserve and south of Waldaira Lake. It also occurs on red-brown earths in other chenopod shrublands such as communities 8, Black Bluebush and 11, Bladder Saltbush with *Sclerostegia,* throughout the north-east sector of the map, for example on the Ivanhoe road north of Box Creek and along the old drainage line of Box Creek following Prungle Mail road, though separate populations are too small to map.

Community 20

Bull Oak

Structure: open woodland *; isolated plants - isolated clumps **

Characteristic species
Allocasuarina luehmannii

Soils: Deep brown and red sands and sand-loam.
Occurrence: This community is found on sandy rises in the south-east of the map. Usually it is seen as a few single trees, rarely in groves as in *Casuarina pauper* and usually in association with *Callitris preissii* subsp. *murrayensis.* It is more frequent further east and thought to have originally occurred in association with *Callitris* which has been removed for fencing and building purposes (Cunningham *et al.* 1981). An example in the mapped area is near 'Lyle' south-east of Balranald in the *Callitris* Mixed Woodland mentioned in the description for community 16. Isolated trees are found on the corner of the Swan Hill and Moulamein roads south of Balranald. Also present here is Wilga (*Geijera parviflora*), *Acacia oswaldii* and *Callitris preissii* subsp. *murrayensis* and mallee nearby. This community was not extensive enough to be mapped as a separate unit.

Community 21

Cottonbush

Structure: low shrubland *; open - sparse chenopod shrubland **

Characteristic species	Associated species
Maireana aphylla	*Atriplex vesicaria, Atriplex leptocarpa,* *Nitraria billardieri, Sclerolaena* spp. *Calocephalus sonderi, Rhodanthe stuartiana,* **Cotula bipinnata.*

Soils: Yellow-grey and grey clay soils.
Occurrence: Restricted to the south-eastern corner of the map on flat plain country south of the Murrumbidgee River, for example along the Keri Keri Rd.

Community 22

Dillon Bush

Structure: low - low open shrubland *, sparse shrubland **

Characteristic species
Nitraria billardieri

This community usually occupies a disturbed area and can occur within most communities as a result of overgrazing or clearing. Associated species vary depending on the original vegetation. Usually there is a high percentage of grasses, weeds and annuals with the occasional shrub for example, *Einadia nutans, Sclerolaena* spp., *Atriplex* spp. Annual grasses and Asteraceae commonly occur. *Nitraria billardieri* may be only present as an occasional shrub.

Soils: Usually clay and loam soils, often saline areas. In the Lowbidgee the soils are strongly gilgaied grey self-mulching clays (Pressey *et al.* 1984).
Occurrence: On plains and floodplains throughout the region, predominantly in the east, such as dry lakebeds that have been grazed or left after cropping, overgrazed areas, and previously cropped areas.

Community 23

Great Cumbung Swamp

This unit was not sampled and is taken from Pressey *et al.* (1984).

Structure: closed - open herbland *; closed - open grassland/forbland **

Characteristic species	Associated species
Phragmites australis *Senecio cunninghamii*	*Paspalum distichum, *Cirsium vulgare,* *Pratia concolor,* often with **Hordeum leporinum & *Polypogon monspeliensis.*

Within this unit *Senecio cunninghamii* occurs on the higher ground on the edge of the swamp, with *Phragmites australis* in the swales and down to the upper limit of *Typha orientalis* which grows in the water.

Soils: Heavy clay soils.
Occurrence: In the Great Cumbung swamp at the far eastern edge of the map.

OA Open Areas

"OA" indicates "open areas" occurring mostly on the aeolian soils of the mallee country. They are thought to be naturally occurring areas of heavier soil (Eldridge pers. comm.) supporting shrubs, herbs and grasses. Within the Sandplain Mallee many of the "open areas" follow old drainage lines. Within Mallee Cliffs National Park, Morcom and Westbrooke (1990) referred to these areas as "herbland - open herbland" resulting from the modification of chenopod shrublands or arid woodlands caused by grazing pressure.
Some of the less disturbed open areas to the north of and on the eastern boundary of Mallee Cliffs National Park support Pearl Bluebush (*Maireana sedifolia*) shrubland (community 9). Closer to tanks stocking pressure may have reduced many of these areas to predominantly grasslands. South of Mallee Cliffs National Park the open areas occasionally have patches of Belah, (*Casuarina pauper*).
Open areas in the mallee west of Euston are a result of frequent prescribed burning. Three fires in the space of seven years has led to a depletion of mallee in the swales creating open grasslands (Noble 1984).
Common species include *Sclerolaena obliquicuspis, Stipa nitida, Stipa nodosa,* often with *Dissocarpus paradoxa, Salsola kali,* and **Silene apetala.*

Vegetation Structure: Specht (1981) = *; Walker and Hopkins (1990) = **
* when placed before a species name, indicates the species is exotic.